MODERN ORGAN TUNING

BY HERMANN SMITH

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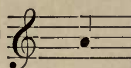
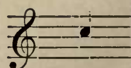
MODERN ORGAN.. TUNING.

COMPARATIVE TABLE OF THE VIBRATIONS THROUGHOUT THE EQUAL-TEMPERED SCALE AT THE THREE PITCHES.

Diatonic and Enharmonic. Greek.		A 430·54 C 512 Standard Philosophical.	A 435·45 C 517·84 Diapason Normal.	A 454 C 540 High English.	Corresponding Note on the staff.
213·33	A	215·27	217·725	227	
	A♯	228·07	230 675	240·5	
240	B	241·631	244·39	254·86	
256	C	256	258·92	270	
c♯ 266·7 d♭ 273	C♯	271·222	274·30	286	
288	D	287·350	290 62	303	
d♯ 300 e♭ 307	D♯	304·436	307·90	321·05	
320	E	322·540	326·22	340·11	
34 ·33	F	341·718	345·62	360·4	
f♯ 360 g♭ 368·8	F♯	362·038	366·17	382·76	
384	G	383·566	387·93	404·46	
g♯ 400 a♭ 409·6	G♯	406·375	411·00	428 5	
426·66	A	430·540	435·45	454	
a♯ 450 b♭ 461	A♯	456·141	461·35	481	
480	B	483·263	488·78	509·67	
512	C	512	517·84	540	

Until the investigations of Dr. A. J. Ellis and Dr. Koenig the Diapason Normal was believed to be exactly 435 v. In May, 1880, Dr. K. especially determined it to be really 435·45. Hence all forks that are copies of it are nearly half a vibration sharper than marked, therefore, throughout the scale the ordinary calculations made upon the older basis are inaccurate

Hermann Smith's "Modern Organ Tuning."

"The Ear is the Umpire of Sound."—*Master Tansur.*

Modern Organ Tuning

THE HOW AND WHY?

CLEARLY EXPLAINING

THE NATURE OF THE ORGAN PIPE

AND THE SYSTEM OF

EQUAL TEMPERAMENT

TOGETHER WITH

AN HISTORIC RECORD OF THE EVOLUTION
OF THE DIATONIC SCALE FROM THE . . .
GREEK TETRACHORD . . . .

BY

HERMANN SMITH

Author of "*The World's Earliest Music,*" and
"*The Art of Tuning the Pianoforte,*" etc.

Date?

∴ An old bk.-see p. 50

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TO THE READER.

I HAVE often been asked to write a book on Tuning intended specially for those who are engaged in organ work, whether in the building of organs, or in the playing of organs, professionally or otherwise. The demand for new editions of my former book "The Art of Tuning the Pianoforte" encourages the hope that my present task will be justified by a similar degree of usefulness.

In that Pianoforte treatise my aim was "to enable the musician to tune his own pianoforte"; in the present case however I cannot start upon the same footing, with the advice that every Organist should tune his own organ, foreseeing that such an incitement, if it took effect, would certainly lead in most instances to disastrous results to the organ, palliated only by the gratitude to be won from organ builders for the additional amount of work thrown into their hands. The risk of damage to pianoforte strings was but little and such as might be measured

by shillings, but the trouble in an organ by amateur intrusion would probably run the charges up to pounds for setting matters right again.

Modern Organ Tuning is carried out exclusively upon the principles of the system of Equal Temperament, since the old methods of the Mean Tone Temperament, and of the later Unequal Temperament, can only be occasionally found in benighted places, where life moves slowly. There were many engrossing problems in the old-time tuning, and they occupied the attention of some of the wisest mathematicians, but although these problems have possibly had their day, there yet remain in the same field of thought many diversions ready to engage intelligent enquiry; wherefore I trust that Modern Organ Tuning will prove to be a desirable guide in the practice of the art, and that musicians likewise will find in its pages "a record," interesting in itself, one useful to have in a handy form concerning some matters in the history of the development ot music.

HERMANN SMITH.

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MODERN ORGAN TUNING.

SECTION I.

The Purpose and the Plan.

The choice of Treatment.—The particular information upon Tuning given in Books on Organs is usually too brief in statement to satisfy the enquirer with a purpose, its conciseness gives him the impression of vagueness, and he wants to ask questions; the directions are plain enough and complete as far as they go, yet he feels that he is left to follow them blindly, and is not sure how long such confidence as he yields will carry him onward to the end desired. Should his views be confined to trade utility then possibly the instructions he therein finds may, as book knowledge, suffice to put him in the way of practice, or to improve what he already knows, and his personal interest ends there.

Other seekers there are whose intellectual promptings lead them to higher sources, they dip into scientific works, they try "Acoustics" and "Temperament" as found in Treatises and Encyclopædias, and apply themselves seriously to understanding what they read; these seekers are the temporary seekers, they cannot be classed with the students proper, those who settle to a course of study, and to whom the treatises written by teachers who are authorities upon the subject enquired for, give abundant brain work, those teachers in consequence being to them satisfying as expositors. Special

books also there are for students in which information upon all the various systems of temperament may be found gathered together, and mathematically expounded.

My audience.—The seekers I have in mind for my audience, are those chiefly who are to be looked upon as "wanderers" in a chosen region, either by inclination, or having a definite purpose, explorers desiring to acquire knowledge of a particular kind for the pleasure of self-enlightenment. For many of these the academic form is too dry, it leaves them athirst, and knowing this, by long experience, I incline by preference to the daily freshness of the familiar style, as the most suitable for popular exposition.

I do not propose to add to the number of books published upon organ building for amateurs, that field has of late years been fully occupied, neither do I intend to describe the arrangements of sound boards and pipes or to enter into details of mechanism, which everyone in the least degree conversant with organ construction already knows. The organist who is in practical touch with the organ factory, will soon learn how far it is permissible for him to attempt the rectification of matters that have gone wrong, whether in tuning, or in structural details, but the organist who is ignorant of organ interiors and their conditions, or who is without natural mechanical aptitude, should be content to keep his head on the outside, rather than run the risk of disturbances more serious than those that vexed him. It is so easy to make matters worse.

My note of warning should not be read as designed to debar everyone except trained tuners from undertaking to tune the organ in any degree. The question is an

individual one, and probably to be ruled by circumstances. If an organist feels himself fully equipped in knowledge, and is in a position to take the responsibility by all means let him try. Every adventure is an experience. To faintheart I would say "Fear not, be of good cheer, but don't raise the dust."

In writing this little book my endeavour has been to explain to all sorts of people, in a way they can understand, the how and why of organ tuning. There is nothing abstruse in the matter whatever.

Modern Organ Tuning is written :—

For those who know nothing about it, and want to know more.

For those who know something yet are eager to strengthen their musical standing, are anxious it may be, to be more thoroughly grounded in the nature of these things, and of the mind's way of dealing with them on scientific lines.

And, for those who always find interest in musical matters, and gladly gather information from whatever source may seem likely to make good additions to memories storehouse, to present new readings of the past, to offer novel insight into things thought, and perhaps prepare occasion for a pleasant outlook of comprehensive views for future moods of contemplation.

The Plan.

First,—to lighten the subject, and for artistic interest in the past—we proceed by way of historic development, and tracing the origin of the organ to the single pipe common to the people of early times, find in *the lay of the fingers* the first apportionments of a musical scale, a scale or system of four notes or sounds, accepted by the

voice as accordant with natural inclination, and by the ear as agreeable, a scale which is the foundation of our diatonic scale, and indeed of the music of every clime where musical scales are known.

Next we compare pipes with strings, and see in pipes the first determinants of fixed tones, copied as standards of pitch, vouched for by the voice originally, and maintained true by the tradition of the ear. Strings having no permanence of pitch beyond the hour, and requiring to be verified from time to time by the ear could not be bearers of a standard of pitch, nevertheless, since strings by the lyre and monochord, were the only means by which the ancient theoreticians demonstrated the laws of their musical system, we are obliged to bring them into our scheme of elucidation of our own scales, as derived from the old Greek astronomers and mathematicians, for with them, as with the Egyptians who were their teachers, music was allied to astronomy and to doctrines of "the music the spheres."

We then take up the earliest Greek scale, and are led to see how, in historic record through a period of a thousand years, it grew and grew under the hands of their famous philosophers, until it became the complete diatonic system.

A strangely long period of evolution (750 B.C. to 250 A.D.), and at its close, harmony, even then, unthought of. And stranger still—these ancient philosophers knew nothing of the real thing, they spent so much thought upon, so many days, nay years, of speculation and study and experiment. Yet they arrived as it were by a fortuitous course, almost at the very verge of the truth ; there needed but another step to make the discovery,—not for another thousand years was the

secret revealed, and the disclosure of the important truth was reserved for a great astronomer of a different race equally gifted.

The organ now takes up the tale. The adoption of the Greek modes in the vocal services of the Church, and the changes they underwent, although points of musical interest do not concern the present enquiry, so passing over many centuries, during which the instrument was but a clumsy aid to the Church, a time at last is arrived at when harmony having developed, the fixed tones of a keyboard, with duo-decimal scale are found to be incompatible with harmony; hence a demand for some kind of "temperament," so called, hence long periods of use of "mean-tone temperament," "unequal temperament," and in the end "equal temperament," which rules at the present day, and after all takes us back to the old Aristoxenean equal scale of twelve semitones, 350 B.C., a scheme unpracticable then, but now by science readjusted for practical ends. This is the scale to be tuned to, by us to be equalised with full sense of the progressive increase of vibrations in the rise of the steps of pitch; and for this equalisation, absolutely accurate means of accomplishment are provided.

Completing the historical cycle, the way is open to discourse upon the nature of the organ pipe, to investigate the causes of the always "out-of-tuneness" of the organ, and why it should need tuning, to show that all the open pipes of the organ are really closed pipes, that in music itself there is no octave, that there is no consonance but the unison, that there are no possible ratios applicable to music except vibration ratios, no tuning that is not a rectification of numbers, and other seeming

paradoxes worth thinking about, by those who can go beyond the duplicities of words, and look upon the facts of nature face to face.

Finally, the whole theory of Tuning is thoroughly gone into, and step by step fully explained. Tables are given of the figures of the Vibration-ratios belonging to the several notes of the scale calculated upon different standards of pitch. Tables also of the beats which arise from Tuning, and their proportional numbers given for the chief intervals in the progression throughout the scale, and the process shown by which these are arrived at with scientific precision. The different methods that are practised in organ tuning are also explained, and a body of instruction presented which it is hoped may be read with profit by many inquirers, and may, perhaps, stimulate to more earnest observation.

SECTION II.

The Origin of the Organ.

In the early days.—The organ can be traced back to very ancient times in history, even beyond the land of myth. Pan is the reputed designer of the first collection of pipes of different lengths, bound together and blown by wind, and the Syrinx or Pan's pipes is the true representative of the ancestry of the organ ; seen in our Punch and Judy shows it is a curious instance of survival of primitive design.

The Greeks were much given to crediting a complete and perfect type to their mythical originators. Apollo had his complicated Lyre as Pan his completed pipes, yet it is evident from what we know of progressive civilisation that long periods of time must have been passed before such a condition, showing marvellous ingenuity, could have been attained in instruments of music. Single pipes would first have been handled and brought into use, then two. When two pipes were first combined and held in the mouth to be played by one breath, then we may consider the organ was foretold. Many instances of such double pipes occur in other lands more ancient than Greece.

The earliest Pan's pipes consisted probably of not more than three or four pipes. This may be inferred from the lyres of the earliest period which shows but three strings.

The method at first adopted with pipes, of blowing across an open end, was the most natural we can

imagine; then a hole formed at the side of a pipe such as we have in our flutes seems as easy for producing sounds, and it was but a step to add other holes. Another method chance experiment brought about, which was necessary before our organ could begin to show any mechanical adaptation. In cutting the reed-stem accident would soon reveal that the joint afforded a half plugged top, and this diminished hole would be equally fit for producing sound, and again, a simple slanting cut would at some early period lead the way to the whistle form at the head of the pipe. This familiar form is called "the fipple." When invented, or by whom we cannot tell, history has no record of the time when this most important change in the pipe took place, giving the mouth a new control over the pipe. The fipple mouth was a significant advance simple as it was, fixing the type for after ages. The organ is indeed founded upon it, our great diapasons being but whistles, and all the flue or flute work nothing but whistles. At some early time, too, another discovery was made, when some followers of Bacchus found that the goat-skin in which they stored the wine, could be used to play the pipe, and the wine bag became the wind-bag. The bag-pipe was a very great advance in organ-work, since it suggested the still greater invention a bellows weighted, so that by pressure the strength of tone was increased.

The most ancient Organ.—The earliest representations of an organ are crude, and shew only six or seven pipes stuck up on the top of a little box. Wherever early organs are illustrated or spoken of the dates are surrounded by uncertainties. One certain point is established that Cestius, an Egyptian, invented the Hydraulic

Organ about 300 B.C. and as that exhibits much mechanical knowledge we can thereby judge how long a period must then have elapsed since the time when the most simple ancient organ had a real existence.

As the centuries passed, pipes were added to pipes. At first it seems that the admission of air was effected by a slider under each pipe like the lid of dominoe boxes, for it was for the separate sustaining of tone that an organ was wanted, and we are told of sounds from organ pipes that could be heard half a mile away, and from Jerusalem to the Mount of Olives. At long gaps of time more pipes were added, then valves, and rods to pull down the valves by a string, then keys, (though it is doubtful, even by centuries, at what date the actual keyboard was brought into use), ranks of pipes added to ranks, then pedals, and at some intervening date, we know not when, the reed-pipes, and in this fashion the Organ grew. How long a stretch of history it is from the little beginning of Pan, up to the great organs that are the monuments of our own times.

Pipes or strings ?—After Pan came Apollo to whom the Greeks say they were indebted for the seven-stringed Lyre. The ability to produce an instrument with this number of strings implies considerable skill in workmanship. The question as to which came earliest as the progenitor of a musical scale, pipes or strings, is answered in favour of pipes, because at a time when civilization was in its childhood these were easiest to obtain and bring into use ; to provide lengths of string made from gut that should prove to be of the exact thickness that under tension would give required notes, this must needs have demanded long industrial practice, and education of ear likewise, for strings afford no

standard themselves; whereas pipes fix their standard, so that we, recovering pipes from tombs in Greece and in Egypt, know that they bring to us the standards of tone as existing thousands of years ago, unaltered though sounded to-day.

The voice was the first measurer, was the original standard of pitch for all. And the pipe is delegated to hold the pitch. Leaving the organ for a while, there is matter for thought to be found in the pipes themselves, and the part they played in fixing the primitive scale of sounds, for my conviction is that pipes were the first placers of sounds in relations of such nature as to form a series or scale of sounds and so that by the fact of usage these pipes became lawgivers, were potential in the life of the people, and fixed the custom. Briefly it may be explained in this way,—when men found that they could produce sounds from river reeds or pipe stems of bamboo blown across by the mouth and afterwards could obtain and vary such by making side holes, the lay of the three or four fingers would first cause them to place the outlets or sound-holes in the easiest position for the fingers, and it would be afterwards that they would notice the relation of the sounds and be set seeking by little shiftings to make the sounds correspond nearly with some of the accustomed tones of the voice. In fact, the first of impulses is the impulse to imitate, and imitation becomes a subsequent factor in heredity. Old examples of the Egyptian "summarah" and "arghool," shew how enduring are the old habits and feelings, for modern specimens differ but little from the most ancient.

The exact ways of development can only be guessed at now, but there is a large amount of evidence tending

to induce and confirm the belief that the set of fixed sounds popularly adopted as the scale for pipes, gave the law to the strings in the first instance for imitation.

The Egyptian pipes just named are sounded, not flute-like with mouth-hole, but by little strips of reed cut up from the body of the pipe as in a boy's oat-straw squeaker, a method so ancient that the pipe with a beating reed was most likely the first in order possessing the series of sideholes, and establishing a scale.

In these two forms of pipe, the flute-pipe and the beating reed-pipe, are found the remote ancestors of the organ; between the new and the old are many Eras of Civilization,—nothing more. At the present day the ingenious compilations called "specifications" make heavy demands upon our faith, yet all their lists of high-sounding words are reducible to two terms,—the Flute Department, the Reed Department.

Another department of investigation will next occupy attention, namely, the origin of our musical scale, after which the Organ topic will be resumed.

The enquiry into origin.—The enquiry embraces two distinct subjects, the origin of the organ, and the origin of the musical scale. These two are so linked together in our design that, for clearness sake, I am compelled as it were to take them in parallel lines for investigation. If there is a little repetition it will not harm the steady advance.

The whole attention of Greek philosophers, who amongst their studies astronomical and mathematical, included music, seems to have been directed to strings. Upon strings alone their learned disquisitions have been written. I do not know that they make mention of pipes for investigation. With the Chinese it was the

opposite. They had a complete system of the lengths and proportions of pipes, and made their little She'ng organs long before nimble-footed Pan piped in the groves of Dodona to illusioned Greeks.

Pythagoras quite in the dark.—Men of various races were in early days long content with three or four notes to form their simple scale of musical sounds, and these comprised what we term a fourth.

Thus the fourth, with its interposed divisions variously placed, constitutes the first musical scale known to men. The Greeks called this a tetrachord. Upon my making the claim for the system of four sounds as constituting the first musical scale known to men, some will be ready to say:—"What about the pentatonic scale?" My reply is that I support myself by the authority of Dr. A. J. Ellis who stated that he had come to the conclusion that the pentatonic scale had been derived from a tetrachordal scale. Let it be plainly understood that I have no wish to trouble any school of harmony. I am an innocent bystander. The enquiry into "origin" is quite apart from doctrines of harmony, yet I have heard that the prejudice unprogressive musicians have in favour of the fifth, blinds many to the essential nature of the fourth as the foundation of the musical scale. The fourth to them is quite subordinate, allowed notice only as the inversion of the fifth. The alienation of thought has been due to Pythagoras, the ancient Greek philosopher. Pythagoras by his scheme of ratios, as demonstrated by the relative proportions of lengths of strings, established a theoretical basis for the musical sounds elicited from them. His scheme, worked out upon the monochord or "canon" as he called it, had a sensible value at that period. To him the fifth was a

cherished consonance, next best to the octave, hence its pre-eminence since in musical learning. Strictly speaking, the unison, it is now shown, is the only consonance, there is none other. This statement is not to be taken as having reference to rules in musical teaching or formal exposition. Pythagoras was completely in the dark as to the true nature of musical sounds, he had no idea of vibrations as affecting pitch, and their ratios as defining intervals, and knowing nothing of harmony as we know it,—

"**He builded better than he knew**"

and although later scientific insight makes it evident that he did not lay his foundations deep enough, he was the first to find a theoretical basis for musical structure, and in his day there was no other more reasonable in view.

What Pythagoras did will be explained in the next section. The system of music existed already, he did not create it, he taught the Greeks how to analyse it.

Step by Step.—How step by step our diatonic scale developed, how it has become what it is gradually by slow degrees,—does anybody know? Certainly. Wise men in their libraries find much; the erudition is deep, and they can expound it in their own way; but it is the way of the student, not intended to attract the casual reader. The "Wanderer" in literature, after reading many pages, would not readily obtain the clear account he was seeking.

My impression, from wide experience, is that few musicians make a thorough examination of the subject; having had occasion to go into the matter of the Greek system on the historical side, I saw how confused it was,

and how necessary to examine author against author in order to arrive at the true assignment of steps and changes in those distant times. For the purpose of this book a clear historic review seems to me a desirable thing, for tuning means the bringing of musical sounds into conformity with some ideal division of a scale, old or new. With this consideration in mind I have thought that it would be useful to take, from my larger paper of enquiry upon the subject, some of the salient points, and to make a brief sketch in the hope that to you it will be acceptable as a record well worth knowing, and helpful also to a better understanding of the systems of temperament practiced in recent times. Taking care not to burden this enquiry with too much learning or semblance of learning, enough may be set out to bring home to the mind the conception of a chain of historic facts.

The evolution of a musical scale should be interesting, even to musicians who would not make the subject a study. At all events my desire has been to make it interesting.

SECTION III.

The Basis of the Musical Scale.

The beginning of the scale.—To begin at the beginning; muscle is the basis of the musical scale. The muscles of the throat and larynx have dictated the primary intervals of the scale. The time and rhythm of music have in like manner in the early stage been regulated by the muscles of the chest, of the arms, and of the legs, simply in the fact, ever in evidence, that they automatically apportion degrees of effort, and times of renewing of effort. Man moves as he must. His race and constitution order his gait and bearing, as they ordain his heart-beat.

Vocal communication.—The organ of voice is so constituted that the healthy muscles find it easier to make, when the mind incites to effort, steps of definite degrees in vocal pitch, than to take mincing irregular steps. This it may fairly be assumed was man's way to a defined division of vocal effort, long before song was thought of as a connection of sounds. Call it vocal communication. To this end the voice suits itself to distance with a natural calculation of effort to effect. If we have to go out of our ordinary talking level, for emphasis, or from emotion, or with the intent to be heard a little distance off, the first natural interval is that one familiar to us as the interval of the fourth, because it is easiest to do so; to rise to the interval called a fifth, means the exercise of greater effort, a more deliberate attempt to arrest attention, and the

voice makes that further degree of effort when the distance is greater than before ; to communicate at a still greater distance will demand a rise of voice to an octave, that is to say to that repetition of a first sound at a higher pitch called an octave. Thus it comes home to our judgment that the use of the voice follows upon predisposed lines, as is the case in walking and in breathing.

In all our argument it should be borne in mind that the terms, fourth, fifth, octave, are quite artificial, are signs founded on *vision,* or the numbering of strings of the lyre.

When did music as a system begin ?—As music, the beginning of a scale might well be believed to have originated in religious use spontaneously. Intervals of vocal pitch belonging first in accustomed use to the daily life of man, were naturally taken and incorporated in the earliest rites and ceremonies, however rude the civilisation. Savage tribes now give warranty for this ascription. By priestly intonation in appeal to the Gods, the rising and falling of the voice by rule in a certain manner, became a custom, and in time a formal regulation by authority. Research shews that with the peoples of Persia, India, China, Arabia, Egypt and Greece "the fourth" was the chosen interval that was the basis of the musical scale of each ; both in the pipes they used, and in the stringed instruments, the evidences are the same. The civilisation of these peoples dates back to ages so remote, that although many thousand years yield records of established usage of scales thus founded, yet without question it must be acknowledged that to reach that state of civilization vast periods of time had been necessary.

Dr. A. J. Ellis states as the result of his enquiry into

139 different scales of various nations that his assured conclusion was, "the predominance of the fourth, and the mere evolution of the fifth, in Greece, Arabia, India and Japan. . . . the fifth never had the same predominance as the fourth."

The system of the Tetrachord.—Having become known to us through the writings of certain Greek philosophers fragments of which have been preserved, the system of the Tetrachord has therefore been assigned to the Greeks, and the development of it has been recorded only in their language. Yet its origin is undoubtedly Egyptian, long before the time of the Greeks.

The Lyre being the typical form of instrument in which the tetrachord was in evidence, the attention of philosophers was given to *stringed* instruments, pipes having no share in their regard, possibly because the playing of pipes was a professional art, whereas any philosopher could twang strings.

The invention of the primitive lyre is attributed to Mercury, and his instrument had but three strings, corresponding, it was said, to the three seasons into which the Greek year was divided. This evidently was but a variant of the Egyptian tradition giving to Hermes the lyre of three strings, symbolising the three seasons of Egypt, spring, summer and winter of four months each. A three-stringed lyre is shown in several Egyptian wall-paintings, it is carried lightly on the shoulders of women in the procession ; whether the several strings had any prescribed pitch, or were only struck to point the rhythms of the chant or song we cannot tell. It is said that Linus added the "lichanos" or forefinger string, making the fourth string. The lyre of Mercury, so tradition asserts, had the three strings—

thus comprising the fourth, fifth and octave, according to our terminology.

e—a—e, or, *e—b—e*.

The evolution of a scale.—Emerging from the mists of fable we hear of an early period in which the octave became disused, and nothing remained but the fourth in its rudimentary condition, divided next into two steps, and after that separated in three divisions resulting in an interval comprising two tones and a lesser tone, or two steps and a half, so that the whole is marked by four sounds ; this series then undesignated, arrived after a time at a stage when it *was* designated, and known thereafter by the word "tetra" signifying "four," and the inclusive system was called a "tetrachord."

We import our ways of speech upon musical subjects, into the consideration of these ancient matters, and necessarily so, but it is essential to a right apprehension to remember that Greeks had no other way of naming the sounds except by the names they gave to each string, thus the forefinger string was called "lichanos," and the others had their distinct appellations. They had no sense of tonic as we have, no system of harmony, no musical stave, no use of the letters *a, b, c,* etc., to denote their music. In later times they had a kind of letter note method, curiously crude, yet elaborate, of alphabetical letters upside down, letters lying on the side, letters mutilated, and signs for instrumental sounds different from those for the sounds of the voice.

This knowledge was by the merest accident preserved to us in a solitary manuscript by Alypius 115 B.C.

The earliest Tetrachord—.For many centuries previous

to 700 B.C. the Greeks seem to have been content with one system of four sounds or notes. By them Music was regarded as an aid to regulate by rule the inflections of the voice, the emphasis and the pauses in the recitation of their epic poetry. Innovation was prohibited by law, but in the course of time laws were overlooked.

The most ancient form may be represented thus, considering the extreme sounds to embrace the interval,—

e⌣*f*— —*a*

it was the initatory stage afterwards completed as,

e⌣*f*—*g*—*a*

only that it should be read from right to left.

(The sign — indicates whole tone, and ⌣ semitone).

The man's voice was the guide, and from time immemorial the *a* was the standard of pitch, by ruling of the ear.

(The *a* below middle C—top line—bass clef).

From father to son, from teacher to scholar, the tradition of pitch was carried on. The string affected by heat and by moisture, and by the strain when twanged, never remains accurately to pitch, and although pipes and strings have run a parallel course, we find no evidence of pipes being actually cared for by lyre players as guiding them in setting the pitch. Plutarch tells us that it was the custom for *reciters* to have a pitch pipe sounded by an attendant to keep their voices to the pitch and mentions an ivory pipe being used for the practice, but from earliest times it would seem that lyrists of all sorts, and players on stringed instruments of every nation, find the habit of the ear sufficient for the purposes of their art, that indeed, the musical ear relies upon itself for tuning.

The laws of the tetrachord. The strings were tuned in relation to the *a*, falling a fourth to *e*. The extreme sounds were fixed sounds, the two inner sounds movable in small degrees; the two upper notes were to be a whole tone apart and the two lower notes a semitone apart, though the exact extent of these might vary, so that the question was, the largeness of the semitone. There is reason to believe that a division had been attained, tuned by ear, giving very closely both a true major third from the one extreme note, and a true minor third from the other extreme note.

Under these simple laws, the lyre existed up to the time of Terpander, who added three strings. Now why was Terpander allowed to do this? I think I have found the solution, as will be seen presently.

The historic record which I have worked out and here drawn up, will, I imagine, give a clearer idea of the development of the primitive scale than the "Wanderer" could obtain for himself by the reading of many books. The dates are given as about the time in the man's life when his public doings were likely to be recognized as of importance. Generally, in history, the names are associated with dates of birth and death, as inclusive limits.

The Historic Record.

From the foundation of Athens, B.C. 1556 to the time of Terpander *circa* B.C. 650, a period of nine hundred years, the ancient racial or inherited system of the tetrachord retained its hold upon the people.

a
g
f
e

The original names given to the strings are probably

lost, for instance, the highest, the *a*, could not have been called the *mese* or middle, there being no middle position until Terpander added the three above *a*. The enlargement of the lyre from four to seven strings was a very serious change. This was his scheme, from *a* down to *e*, from *a* up to *d*.

$$\underbrace{e\smile f-g-a}_{1}\overbrace{\smile b\flat-c-d}^{2}$$

$$\longleftarrow\quad\longrightarrow$$

Olympus about B.C. 630 changed this as follows, and obtained the octave on the seven strings

$$\underbrace{e\smile f-g-a}_{1}\underset{*}{-}\overbrace{b-\quad-d-e}^{2}$$

Notice particularly the interval *b*‿ —*d*, as it plays an important part in the history of music. It was a flute-pipe interval, older than Terpander.

Anacreon, about 540 B.C. had a ten-stringed lyre, each string having a division by a bridge or bar causing it to produce its octave, the lower portion being half the length of the upper portion, but this instrument was the old Egyptian magadis.

Pythagoras, about 530 B.C., added an eighth string, and it is evident that the string he introduced was that for *c* since the octave already existed as to extent.

$$\overbrace{e\smile f-g-a}^{1}\underset{*}{-}\overbrace{b\smile \underset{\text{x}}{c}-d-e}^{2}$$

therefore two complete tetrachords, but disjunct. It is plainly to be seen that he wanted a fifth to the *f* to make his scheme of fifths perfect. It was a marked advance.

Ion, about 430 B.C. enlarged the lyre to ten strings, and was the author of the Conjunct or Lesser System complete. It consisted of three tetrachords conjoined and one note added to complete the octave *below, from mese,* the middle note *a*. Greek names would bewilder, and it will be the best plan to keep to the method of distinguishing the notes by letters.

$$a - \underbrace{b \smile c - d}_{2} - \overbrace{e \smile f - g - \underset{*}{a}}^{1} \smile \underbrace{b\flat - c - d}_{3}$$

Notice the return to the Terpander scale with the *b* flat.

This was the state at which, after two hundred years, the scale had arrived. After Ion there came a period of controversy.

Archytas, 400 B.C. challenged the Pythagorean third, he was the first to show that *c*— —*e* should bear the ratio $\frac{5}{4}$.

Aristoxenus, 350 B.C. disavowed the whole Pythagorean scheme, and the philosophers ranged themselves in two opposing schools, the Pythagoreans who determined intervals by proportional numbers, and the Aristoxenians who relied upon the judgment of the ear. Somewhere in the period embraced by the lives of Ion and Aristoxenus, for it was a period of high intellectual activity with the Greeks (Sophocles, Pericles, Plato, Aristotle, and other famous men were living), somewhere we have to place the Disjunct, or Greater System Complete,

$$a - \underbrace{b \smile c - d}_{3} - \overbrace{e \smile f - g}^{1} - \underset{*}{a} - \overbrace{b \smile c - d}^{2} - \underbrace{e \smile f - g}_{4} - a$$

then there was *an alternative arrangement* ultimately ad-

mitted, making conjunction at *a* allowing *b* flat instead of *b*, so that the tetrachord ended on *d* and the tone of disjunction was placed between *d* and *e*. Very noticeable this as showing how popular feeling hankered after the old way of Terpander. This later Greek scale, comprising two octaves, first comes to us from Euclid's works (some add "reputed") of the third century, B.C. 323-285.

Eratosthenes, B.C. 276-196, was the librarian of the great library at Alexandria, founded B.C. 332, by Alexander the Great, and his name figures largely in the mathematics of music.

Two other Alexandreans complete the record, they lived within the Christian era.

Didymus, A.D. 60. He demonstrated the lesser or *minor tone* to be necessary to the right division of fourths and fifths.

Claudius Ptolemy, A.D. 130, accepted this scheme, but altered the arrangement of the tones. He perfected the diatonic octave scale by strict rule logically applied, and as he left it so it remains, practically the same, in use to-day.

$$a—\underbrace{b\smile c—d—e}\smile\overbrace{f—g—a}^{}_{\;\;\;\;\;\;*}$$

Read it from right to left, two tetrachords, with added tone at the bottom. The schemes of these two, Didymus and Ptolemy, are more fully explained on page 32.

The historic point at which we commenced was the time of Terpander, variously stated, the only date known in his life was the year when he gained for the

fourth time in succession the prize in the competition for singing, B.C. 676, at the Pythian Games.

Athens was founded by Egyptians, as was Argos, as were other Greek cities, and as was Etruria by an offshoot of Egyptians probably, and afterwards colonized by Greeks. The centuries passed and in the year B.C. 664 there arose in Egypt a new Pharoah of the XXVI. dynasty, Psammetichus the First. Heretofore the people of other nations had been rigidly excluded from Egypt, Psammetichus discarded the old policy and admitted all foreigners to trade and intercourse. Here in this great change is, I think, the explanation of the innovation ventured upon by Terpander, notwithstanding so many centuries of Greek exclusiveness in music; for the Greeks withstood innovation as strenuously as the priests of the old country had done. When these people left the motherland they took with them the common popular music such as themselves and their families had been accustomed to; as a band of military adventurers they had no need or use for any other. Hence the simple tetrachord remained as their system of music, and had not been extended. A remark of Herodotus who travelled in Egypt about the time of Ion corroborates this view of their music as inherited. He tells how he was struck by nothing so much as by hearing what he had thought to be a famous song of Greek origin, but which he then learnt was a most ancient Egyptian one, a mourning dirge for the premature death of the only son of Menes, the first King of Upper and Lower Egypt, and that it had been sung for countless generations as a lament for Maneros. The Greeks having changed the name of it to a lament for Linus. Menes reigned about B.C. 4750.

Before the opening of Egypt there was no doubt a preparative period of several years when new ideas were in the air, when ruler and peoples alike felt the impulses of adventure and commerce. The new state of things was of far reaching importance, the intellectual gain to the outside world was very great, travellers from all parts flocked to the Nile, astronomers and mathematicians, philosophers and scholars, congregated to search for the ancient knowledge wherever stored.

After "that great gap of time" which had separated them, the Egyptians taught the Greeks musical science, and thus it happened that at this particular period the Greek tetrachord started a new growth, and extended from four to seven strings, from one sacred mystic number to another. Although by conventional form a part of the land of Africa, Egypt by race and civilization belongs to Asia, and is an arm stretching out westward from Chaldea, always having shared the destinies of Asiatic empire. As a racial question, the Lybians are considered as the original dwellers on the land, they being later conquered and absorbed by invaders from the coast of Arabia.

In the Olympus octave of tetrachords, the skip of the semitone suggests a pentatonic influence, and Olympus is said to have introduced Asiatic flute music into Greece. In point of fact it was Egyptian flute music. The models I have of the Lady Maket flutes, that were three thousand years old, possess this particular skip between two notes, models also that I made of Greek flutes of a thousand years later date shew the same, the originals in the British Museum I had in my hands for measurement. Most conclusively the study of old musical

instruments shews that primitive peoples had a liking for that interval *b*⌣—*d* vocally, and on the flutes it would have been copied from the voice ; or the converse might be maintained, that the fingers on the flute determined the interval and fixed the liking of the voice for it.*

Pythagoras.—His great name overshadows music still, many doctrines have been attributed to him, but how far rightly we cannot know. Pythagoras spent eighteen years or more of his life sojourning in Babylonia and Egypt, and brought back to his own land the knowledge of many things learnt from the priests in the Temples of Egypt. The number "four" was a sacred number to the Egyptians. Do not lose sight of the truth that the science of music began in numbers, astronomy had in that day attained a high degree of excellence and was then considered a branch of music. A superstitious idolatry of numbers persists through the science and philosophy of the ancients, tribes and nations bending to the yoke of lucky and unlucky numbers, the ignorant and the intelligent alike yielding to some hereditary strain of belief in the portent of mystic numbers, and it has not left us yet. To judge fairly of Pythagoras this should be remembered. Helmholtz says, "The relation of whole numbers to musical consonances was from all time looked upon as a wonderful mystery of deep significance. The Pythagoreans made use of it in their speculations on the harmony of the spheres, and it remained partly the goal and partly the starting point of the strangest, most venturesome, fantastic, philosophic combinations."

*** See my work "The World's Earliest Music," in which this question finds its place. W. Reeves, Publisher.**

Pythagoras taught "sense is an uncertain guide, numbers cannot fail." The Greeks had their complete octave already tuned as they liked it, by ear, he undertook to show them how to tune it better by rule, he proved to them that the octave note was given by a division of the string, as 2 to 1 (this they already knew in the magadis), next that dividing a string in parts as 3 to 2 gave the fifth, and as 4 to 3, the fourth.

Here he stopped. Which was singular. He was so infatuated with the fifth which very likely was to him as the first-born of his theory of the proportions of length of strings, that he went aside from his main principle and worked out the relation of the other notes in the octave by a series of fifths. With the consequence that he got them all wrong, they did not carry out his doctrine of proportions. The followers of Pythagoras were twitted afterwards with the inconsistency of their master. The "third" that went by his name greatly exceeded the proportional true third; he got it by taking four fifths up, and obtained by the process the note that he *wanted* for his inserted string *c*, and the third this made with the *e* above, *that* was the pattern for the third in his scheme. After his death it was found out that there was no reason that the third should be dependent on four fifths, or indeed, upon one. It was an interval in use by vocal instinct; thus, whatever it was, there are no means of knowing, but Archytas showed that the true string proportion should be 5—4, and from this the minor sixth would have followed as 8 to 5 naturally dependent.

Pythagoras taught by the "Kanon" or monochord, which means by several monochords, viz., stretched strings on a board with movable bridges for making

accurate divisions of the string into proportional parts.

Because of the wonderful ingenuity displayed by the Greek theorists in contriving differences of interval in divisions of the octave, the Greek people have been supposed to have possessed marvellous delicacy of ear in detecting minute differences in the tuning of their lyres. Should not it be asked, how was it that this philosopher never found out that the octaves he got by dividing the strings at the half into two parts were flat octaves? Modern methods of investigation place beyond doubt the fact that they must have been so. Sometimes flat by about a quarter of a tone. Dr. A. J. Ellis, and Mr. A. J. Hipkins made a number of experiments upon monochords, which demonstrated to them that the monochord gives very uncertain results, even when estimated by very sensitive ears.

Dr. Ellis states, "Even in Europe now, it requires much practice for the majority to sing accurately in tune or to appreciate small errors. The old intervals were, therefore, not so accurately tuned as was supposed, and hence, when we take them to be accurately tuned, *we are ourselves inaccurate.*"

The directions of the theorists show very finely calculated intervals, but we may be fairly sure that the niceties averred of tuning were not kept in practice; the singers and players did as they liked, much the same as they do now.

Pythagoras claimed that he invented the monochord, and when dying referred to it as "the investigator of music, the criterion of truth." The aim of Pythagoras was to prove that there was a natural law in musical sounds which governed the relations of those sounds to

each other, the same as was shown in the proportions of the lengths of strings to the sounds produced when these strings were plucked, thus he demonstrated the octave to be produced by the half length of the string, the fifth by two thirds of the string, the fourth by three fourths of the length of the string, and the hearer was able to affirm that these demonstrations were just—the appeal after all being to the ear as regarded the identity of experimental sounds with the sounds the singers and players used. There could be then, at that time, no other test. He further showed that a fifth and a fourth were included in an octave, and the fifth overlapped the fourth to the extent of an interval, called a tone. Thus sounds were brought under rule and gained their first start as a science, a science of numbers only. The value was in the "announcing" the existence of law in sounds, not in the use he made of it, which tried by facts, amounted to but little, as we shall see.

The lyrists had the two scales of Terpander and Olympus, and necessarily these gave them thirds within the fourths, and fifths within the two tetrachords if they chose, and the octave. One scheme was conjunct, the other disjunct, refer back to them and you will see that Pythagoras took the latter, and by his re-insertion of the *c* spoilt the old "folk-song" interval *b*— —*d*, the *b*♭—was afterwards taken in again by popular option in the *alternative* that was brought into "the Greater System Complete." The early lyrists looked upon fourths as we upon octaves, as a repeated series, and as they tuned the first by ear, so the second, third and fourth step gave them fourths from the original four notes or strings, tuned upwards by ear, thus they had four fourths in succession to tune. The Arabian

lute was tuned by fourths, and so, we should remember, were the old viols. The tuning of violins by fifths is merely the after adoption, as it were, of the disjunct scheme, in lieu of the older conjunct.

Pythagoras made the discovery, by mathematical calculations (for there were no existing instruments to exemplify it), that by taking a series of *twelve* fifths upward he arrived at a point which just made *seven* octaves and a bit over, a very little difference it is true, but then it was to the Greek mind a numerical feature of deep significance. The aftertime effect in calculations in theories of harmony we should here put aside, and try to see the *curiosity* as seen by the mind of Pythagoras, dominated as that was by "the harmony of the Universe," an idea having a strong hold upon the philosophers of the time. The mystery of numbers came in, the seven octaves would to him represent the starting points of the eighths or octaves, and in the twelve would be found the cycle of the year, by four fifths he had obtained his third, representing one of the three seasons into which the year was divided. Simple numbers, the sacred 4—8—12, yet always the excess; what did it mean? It was like the excess of the circle over three times its diameter; like the excess of the annual number of days by a fraction of a day. The Egyptian astronomers had found that the true year consisted of 365 days and a quarter. In all these things, to the great thinkers, there were mystical analogies. The sun and planets were symbolized in the notes of the scale, Saturn, the farthest off, being denoted by the low *e* and the sun by the *mese a*. Nothing practical came of that discovery of Pythagoras, under his hands it bore no fruit. They called it after his name

"the comma of Pythagoras," to the everlasting benefit of a long line of theorists.

Aristoxenus, a pupil of Aristotle, was a musician, the son of a musician, and he opposed the Pythagoreans, and held that "it was absurd to aim at an artificial accuracy in gratifying the ear beyond its own power of distinction," a decision very natural, coming from a musician. He was a great writer and theorist, wrote, it was said, more than four hundred treatises, all of which have been lost except three on "Harmonic Elements," and this is the oldest musical work at present known. He it was who gave form to the idea of twelve equal semitones for the octave, and proposed that the comma of Pythagoras should be distributed by flattening each fifth in it the twelfth part of that comma. The result would not have been the same as in our equal temperament, it was in theory right enough in melody, but unsuitable for the system of harmony. We have to temper by progressive proportion.

Aristotle in his old age wrote upon music, he called it "the medicine for heaviness." He did not effect any alterations in the scale, but he had marvellously clear ideas about sound, had arrived at the knowledge that sound of every sort originated in *shock*, had observed that the strings that produced the higher sounds moved *quicker* than those giving the lower sounds; but here he stopped, just missed the true perception that would have given the key to the whole problem. And the law remained hidden. "The Disjunct or Greater System Complete," is called by writers of authority "The Enlarged System of Pythagoras," and leads to the mistaken inference that it was the work of Pythagoras himself instead of its being the work of his followers,

which properly it was. The added note below to complete the octave, which also appears in the Lesser System, was probably the work of some one later than Ion. This note was named the "*proslambanomenos*," surely a most comforting word, equal to the word "*Mesopotamia*" found by the old dame to be to her so full of biblical comfort. And the old dame was right, in the sound of many a word there is sweet music to the ear, apart from the meaning which may be, when known, disquieting.

Didymus and Ptolemy, the two latest philosophers who sought to perfect the diatonic scale achieved highly important results by simple means; whereas the octochord as left by Pythagoras, comprised but two kinds of division, the tone and the hemitone (not exactly half a tone, it was the overplus after the measurement of the two whole tones in the tetrachord)—and these, taking *c* as the starting point for our convenience, may be represented thus—in the octave—major tone, hemitone—

maj, maj, he, maj, maj, maj, he,

this was constructed from a series of fifths.

Didymus shewed that the stricter mathematical division (not by fifths), required a lesser or minor tone in place of *one* major, and the amount of decrease went to increase the hemitone to a semitone, thus,—

mi, maj, se, mi, maj, maj, se.

Claudius Ptolemy seventy years later altered this, transposing the minor tone to the second place,—

maj—mi—se—maj—mi, maj, se.

This distinguished philosopher, like Pythagoras, was the child of his time, finding musical analogies in the virtues and the sciences and the zodiac; he by his

genius completed the foundations upon which European music has been constructed, yet he had no conception of the structure that would be raised by coming generations. The Greeks as we see had in the *mese* the principle of the tonic, and they had their final in the *f*, or the *e* below; probably their rule that "*there must be a whole tone below mese*," and so the absence of "the leading note," would itself have prevented the feeling for tonality which belongs to us. The Greeks had also in their scale the elements of harmony, yet they fell short of the realization, and it must ever be a wonder that, intellectual as they were, they missed it. Evolution is the destined way—but it is so slow—so slow.

Looking forward, it would seem that before a system of harmony could grow up, an organ keyboard was essential, for we find that in countries where the organ is unknown, harmony in the true sense is unknown. The organ, first built up as it was on a scale of a few pipes, founded upon some Greek mode, gradually after eleven centuries acquired a keyboard, and with increase of facilities did, in the concrete form display chords in succession (by accident alone of human fingers grouping notes could obtain chord after chord), and so tempted the mind to a new exercise, and the ear to a fuller delight with a growing appreciation.

The philosophers who taught the doctrine of Pythagoras were men of keen intellect, able to grasp the deep problems of astronomy, and were evidently looked up to as leaders in thought.

One thing has ever seemed strange to me, that none ever seemed to have questioned the sufficiency of that explanation of sounds arrived at by analogies of the the divisions of strings. In "ratios" they had a clue,

but they did not follow it up to its logical end. How was it that they did not ask themselves what had become of the lost intervals? In the proportions into which they divided the string, they got one interval but they lost the other. When from the musical octave the fifth is taken, then the fourth, its complemental interval remains; and *vice versa*, when the fourth is cut out, a fifth still is left; but when from a string of a given length, two-thirds are measured off by a bridge, and the sound given from it is found to be that of the fifth to the sound elicited from the whole length of the string, then one third of that string's length remains, which sounded gives not the fourth, but a sound that is the octave above that fifth,—they had the magadis in daily evidence of it; so with the three-fourths of the string, measured off by a bridge, the portion that remains gives not the fifth wanting to it as its complement, but a sound that is the double octave to the whole, which is an anomaly not an analogy. Surely the falseness of the analogy of strings should have been detected. The dilemma was as of a string with the other end cut off. Had but one of these philosophers the sense of human prompting to the question, what has become of the lost interval? perhaps it might have given the clue to a more searching inquiry leading to the discovery of ratios of shocks instead of ratios of stretched strings. But the time was not yet.

"Everything is number and harmony," said Pythagoras. He had done much for music, yet that there was an inkling of doubt in his mind, that he was unsatisfied, desiring deeper insight into nature is evident from "the Enigma," as he named it, which he left to his disciples and followers,—"Why is consonance

determined by ratios of small whole numbers?" To him it was a mystery in the harmony of the universe which he wanted to have solved.

The likeness between things different is the accident of coincidences. In the consideration of the facts of nature we cannot escape the numerical, everywhere coincidences are pressing on observation. The fact that a horse has four legs, "one stuck at each corner," as the boy said, and the fact that a chair has four legs, these two facts have no connection with one another, no analogy, we merely observe coincidence of number.

Similitudes and analogies are inexhaustible, at times they greatly help comprehension in the mental process; the error people fall into is of supposing that they prove anything, oftentimes, indeed, they are but misleading "will o' the wisps," treacherous in leading the reasoning off solid ground to follow illusions. Helmholtz remarks upon the long hold that "arithmetical mysticism had upon the reasonings of philosophers and men of science, how the vain imaginings of likeness between musical tones and celestial bodies, and the leaning of ideas associating music with elements and essences, and even the virtues and spiritual fancies, diverted science from its true range."

Into the minds of the Greeks in treating such speculations we cannot enter. Their philosophers were children of their own time, as we of ours. The way in which old teaching is presented in translation and in comment, is often, I fear, too much tinctured with the tendencies of modern ideas to be accepted as a true reflex of the mind of the ancient thinkers with only the old word of thought for their basis.

Chance has been the good genius of Science.—The apple appealed to the eye of Newton, the steam from the kettle to Watt, the piaster to the ear of Galileo, to the lasting gain of science. This famous astronomer, by chance (it was about 1640 of our era) scraping the milled edge of a piaster with a knife, noticed that on passing the knife more quickly, the sound it made was higher in tone than when moving it slowly. Then followed the reasoning, that quickened time in the transit over the serrations of the coin constituted higher pitch; that not halving but doubling measured the octave; that the progressive increase in the number of shocks in the rise of the scale, was the true foundation upon which to build the ratios of the intervals. The fact that these corresponded with the ratios manifested by strings also was the mere coincidence of numbers. Chance, the good genius revealed vibration ratios. This key unlocked the treasure-house, and the science of music was enriched by the acquisitions in acoustics.

The historic record from Terpander to Ptolemy which I have given of the tetrachord, affords a plain logical review of the evolution of the diatonic scale—the seed developing the flower,—my design herein does not extend beyond. The old chromatic and enharmonic systems were known before Olympus, these are passed by as having lost interest; much intermediate information exists on modes and genera, and mathematical divisions of intervals of infinite variety.

Learning, of the higher grade, is outside the pretensions of this little book. If my teaching is not according to pattern, it may yet be found, let me hope, in some way suggestive, and in some degree illuminative to my chosen company of "Wanderers."

SECTION IV.

The Out-of-Tuneness of the Organ.

The organ never is in tune throughout for a single day, nor for a single hour. This is a hard saying but it is scientifically a truth. Give a few moments serious thought to the natural conditions and you cannot doubt that it must be so. You will be inclined to ask,

What is the use of tuning it?—You mean re-tuning. Because an organ is tuned upon a system of relation of pipe to pipe, and the nearer we can retain the pipe in relation to that system the better will be the outcome musically. Every degree of divergence from the original condition is liable under the natural changes that are going on to become exaggerated, and discrepancies that were small, at last will be found more and more unbearable. Hence the consideration that although a perfect state cannot be ensured, it is a wise policy to keep down the growth of little discordances lest they should become large. An organ depends solely upon air for its musical sounds, and consequently it is affected by every variation in the atmosphere. All day and all night changes are perpetually going on, heat and cold, dryness and moisture, rising and falling, sometimes in great degree, sometimes infinitely small. To the general observer an organ pipe is an empty pipe; science sees that it is full of air, sees that every pipe is internally in motion, is incessantly active whilst it sleeps. The physician will tell you that each human being is constantly surrounded by an invisible perspira-

tion, that without this unseen halo we could not live, that it accompanies us everywhere, varying as the atmosphere and temperature vary. During such changes of heat and cold, if within the Organ the unseen could be made visible, we should undoubtedly witness every pipe simmering and subsiding, the particles of air bubbling and running over at the tops of them, since as a matter of fact the expanding air within the pipe is pushing out millions of particles of air that are nearest the top to make room for those within lower down, more and more expanding, then in an opposite phase at periods of contraction the opportunity would be seized by the crowd outside to get within the pipe again.

Air being so much material, it can be handled and weighed. The practical point for you to understand, is that warmer or expanded air within the pipe is like the outer surrounding air, lighter than it is when in colder condition, and consequently less in weight. This fact is, so to speak, the ground-basis of all that I am going to tell you about organ pipes, and it is of the first importance that you should thoroughly comprehend it.

The weight within the organ pipe.—When work is to be done the weight to be moved is a prime factor in the calculation. If a certain force is at disposal for effecting this removal, undertaken for a specific purpose, clearly the work will be done more speedily; in case of the lessening of the total amount of weight—the problem is of power against weight.

Observation of an organ under atmospheric change very distinctly shews that the out-of-tuneness of the organ is aggravated by the fact that the degree of it differs over the whole organ, the pipes of higher pitch

suffering the most whilst the larger pipes change much less in comparison.

You will want to know why?—It is necessary to remember that whatever the state of the external air may be, the compressed air in the bellows is converted into wind and is delivered at a fixed pressure, and every pipe large and small has to face this fixed strength of wind acting at the mouths of each; thus it is that relatively the smaller pipes, when the air they contain has become lighter by heat, are at a greater disadvantage, and yielding more readily to the unchanging force at their mouths, go out of tune to a greater degree, they are, in fact, extra sharp.

The Original Voicing.—Originally in the voicing and in the regulating of quality, the amount of wind is apportioned and controlled to the need of each pipe, and at that it remains, each stop having its own allotment for power and quality; the stops therefore differing amongst themselves by reason of the scale appropriate to each, it follows that the dimensions of the diameter differing, many diversities of relation to the wind-force will result; as, for instance, by so much as the diameter or as the depth from front to back brings the bulk of the air to nearer approach to the influence of the wind-force, or on the other hand leaves the body of air farther back, more away from its immediate operation. The question of relative diameter is seen more forcibly in the mixtures since they do not proceed in regularity of scale, but break at various points to resume larger diameters, arbitrarily interposed, and from this cause the mixtures get terribly out of tune. There being no uniformity over the whole organ in the operation of temperature and its changes, Nature allows no remedy.

The temporary causes at work.—Chief of these are dryness and moisture. However carefully an organ may have been tuned it is liable any day to be thrown out of tune by these agents of evil. Damp, perhaps inherent in the building, sun scorching through windows, draught currents, and heatings weekly or fitful, these try every part of the organ, and alter conditions of almost every important relation of the structure. Wood never returns exactly to its former state after being subject to these alternations. Very little differences in actions, and valves, and sliders, and in the set of the pipes over them, are sufficient to alter the regulations of wind in their allotted proportions, and to make re-tuning necessary.

Dust, the great enemy.—Many causes may be imagined affecting the tuning, which, trifling in themselves, may yet, multiplied over the organ, accumulate to make serious defects in harmony. Perhaps it would be the fairest way to put down the chief troubles disconcerting the tuning to the account of dust, for certainly dust is the most insiduous enemy the tuner has to encounter. It is everywhere, it comes in from the bellows, and down from the ceilings, and in at the windows. It would be quite innocuous if only it would not move about. The young tuner's remedy is, "sweep it all away," but the old hand says, "let it alone, it's easier" So only the pipes *needing* to be looked to are touched, and dust removed from the mouth or the windway, where a very little lodgment of dust, causing obstruction to the proper issue of wind, will alter pitch sensibly, though it may seem a small matter. Dust dislodged, you know not where it may settle next, therefore move pipes carefully and replace them without shock, and as

nearly as may be let them be facing in the same position as before. The pipes that are to be flattened or sharpened as they stand, tap them with the cones gently, with no more force than meets the demand.

The old hand who knows his business, and wants to get away before dark, disturbs as little as possible. He has learnt his own version of the old proverb and says—let sleeping dust lie.

SECTION V.

The Nature of the Organ Pipe.

The capture of a column of air.—An organ pipe is a piece of mechanism used for the purpose of aiding us to control that elusive substance, air, whilst we with certain objects of our own in view, seek to disturb its equilibrium. We put a pipe around a certain portion of air. The air left to itself is too quick and sprightly for us, but the pipe holds the air in durance, and we can then make it obedient to command. By secluding the selected column of air from the companionable air around, we make our captive impressionable to the artifices we have learned and intend to use.

Just as the only innate tendency of water is manifested in the effort of seeking to gain its level, so air is itself active only in one way, and so to speak, displays its life in a perpetual endeavour to preserve its equilibrium whenever disturbed and from whatever cause. The pipe acts as a delayer of the time of re-gaining equilibrium, since it is only at the ends or outlets that the air column is able to mix with the mass of air outside in any course going on, or that the outward air can gain access to the inside. Sound cannot proceed from an organ pipe unless its interior air is out of equilibrium, or disturbed from a state of rest. So simple a fact as this is worth thinking about. One very obvious conclusion there is (in correction of the common theory of the text books) that no speaking organ pipe can possibly, for a given pitch, be equal in length to the theoretical

calculated length; the column of air surrounded by the pipe differs from free air by being shielded from the intrusive influence of the outer air except at the top of the pipe, and by consequence needs to be shorter to make up for the delay occasioned by that condition, before the pulse of music can break forth into open air. The variation in this matter of length being so great as to range from a loss equal to one twelfth, up to one eighth of the total theoretical length, and in the pedal bass even to one fifth of the whole, as I have ascertained by measurements during long investigations. Other causes combine to this result as will be seen further on. The organ pipe under notice belongs to the flute or flue-work so called. To unfold the argument in due order and succession the attention has to be directed to another condition of air.

Another body of air to be captured.—The capture has to be effected by the feeders of the bellows which take in great gulps of air alternatingly, and force the air into a reservoir where under great weights it is, so to speak, imprisoned until wanted.

The speaking organ pipe.—The process in an organ pipe is in this wise—air moving under pressure forms itself into a *windstream*, and so in an organ pipe the air, which has been stored up in the bellows reservoir under heavy weights, becomes on passing into the foot of the pipe, *active wind*, possessing a calculated degree of strength or working force; the issuing current or windstream coming from the windway of the pipe is directed to pass over the mouth, so as, be it observed, not as supposed to strike the sharp edge of the upper lip of the mouth, but to glide outside as up an incline, unimpeded. If we suppose a little shutter to be placed

behind the lip inside the pipe, so that it could be let down just to meet the languid at the back of the windway, all that would be perceived would be this upward rushing windstream, the strength of which palpable to the finger is (in a large pipe) almost that of a hurricane. Lifting that shutter, instantly a great change takes place, the windstream curves outward ; by reason of its great velocity of motion it sucks at the mouth of the pipe so that multitudes of air particles are carried away clinging to the interior face of the stream and pressing it over in an outward curve, when there ensues for a brief instant a partial exhaust in the body of the pipe : the next instant the stream curves back, strikes inward, and in action becomes transformed into an air-reed waving to and fro, fan-like. This action I have demonstrated, it can be seen.

The air-reed does work.—The kind of motion producing musical sounds in air is called vibration, it is a to and fro movement. We see it in the motion of strings and of tuning forks. Literally, however, it is needful to remember that musical sounds are due to "shocks" rapidly repeated with periodic precision ; such shocks can only come into existence when rapid motion is arrested or reversed in direction ; the swinging of the string is only a method of tugging at the soundboard by the bridge to which it is attached, and this repeated tugging is shock giving, so also the tuning fork in a different way causes shocks in the air by its prongs pushing the nearest body of air away and suddenly retreating, the shocks being the inevitable result of the partial vacuum due to motion arrested and reversed in direction. So, too, the air-reed does work, in its own fashion, and creates shocks of far greater power. The

sole office of the stream issuing from the windway of the pipe is to *exert suction* upon the body of air in the pipe. The work to be done is a stipulated quantity, neither more nor less, in order to produce sound of a specified pitch, and it accomplishes the task by sucking out or abstracting by force some amount of air particles from the bulk of that material at the time lying quiescent in the lower part of the pipe, its greatest effort of power being exerted along the edge of the level of the mouth. Do not lose sight of the fact that it is by its nature an attacking force.

But about vibration?—Follow the course of the air-reed from its outward curve to its return curve inward. How is this? Why a return curve and not a straight upward rush? Because the *velocity of passage* of the wind-stream over the mouth has been converted into a *velocity of vibration.* In the organ pipe a contest of forces has been set up, between the pulling of the wind-stream and the resistance of the enclosed column of air to being pulled or drawn out; the longer the pipe, the longer is the time during which that resistance can be maintained, its degree being comparative, in relation to, and governed by, the strength of the stream. Although the air-reed vibrates, the stream never loses its original function, it is still pulling, but the farther the curve takes it from the mouth, so its hold upon the air in the pipe weakens, till on the utmost limit of distance being reached the two part company and the pipe sucks back its own, and then the air-reed by the partial vacuum itself has created is drawn back, as also by its natural tendency to uprightness, this, however, avails it not against the strong indrawing current, which carries it beyond the line of the mouth, bends and curves it forcibly over inwards.

This inrush of air is called a "condensation"—it is a compression of the air particles by their own impetus. Supposing the pipe imagined be a "stopped pipe," this condensation will reach the stopper and be thrown back with a shock, the shock of the reversed motion; the condensation is naturally returned as a "rarefaction" or expansion, since it is making its way to the free outer air, but at the same instant the air-reed is regaining its strength, the return motion aiding it, and is taking a curve back again, pulling outwards with force. The air-reed, constantly *replenishing itself*, repeats the process over and over again, and the time-distance between each shock so delivered, is equal to the space-distance travelled over, that is to say the length of the pipe, reckoning to and fro.

The phrase I have used "the two part company" may be made clear by illustration.

Take a piece of india rubber band, fix one end to a solid substance, and the other end hold between the fingers, then as you pull, the band becomes thin, gradually more and more attenuated until you reach the limit of its endurance against the force you use, and it breaks with recoil against the point of fixture, and consequently with a shock. Or if you hold the end with only a certain amount of pressure of the fingers, a time comes when the tenuity reached causes the end to slip through your fingers. This is what I mean, that the air-reed with all the force its stream velocity enables it to exercise, pulls by suction upon the air within to the utmost degree of tenuity that it will bear, when it will hold no longer, and breaks back. It is like the catastrophe in "pull devil, pull baker," when the rope parts, with shock to all concerned in the contest.

All open organ pipes are stopped pipes.—It is a mistake, I think, to speak of a stopped pipe as giving an octave graver sound than an open pipe of the same length. Yet so teachers and text-books teach. As grave an error is that which authorities teach, that the wind is directed so as to strike the lip of the mouth of the organ pipe, and there being split upon its sharp edge, it is set in vibration and the pipe is caused to sound. Any one who is familiar with organs knows that pipes there are that have no sharpness of lip, some even have half an inch in the thickness of lip. How the vibration commences, that they do not explain. Correctly estimated, all speaking organ pipes should be regarded as stopped pipes, the only difference being in the method of stopping. The open pipe I consider as two stopped pipes, meeting base to base. The difficulty in discarding the old orthodox view vanishes upon recognising that the upper half of an open organ pipe exists in order that it may act as a stopper. The open end is stopped by a plug of invisible air, and it is as long as half the length of the pipe, whilst the stopped pipe, so called, is visibly plugged by a wooden stopper. Otherwise the open and the stopped pipe are the same in mode of action. If at cricket I hold my bat firmly at the blocking place the ball striking it recoils. If, however, I swing the bat backward, bringing it forward with impetus to the blocking position in the exact time to meet the coming ball, my act is virtually the same, the result the same, only with a far greater strength of concussion, due to the impetus derived from the swing. The being there at the instant, that was the main thing that was to be provided for. The bat represents the face of the wood stopper at the blocking point; that point on the organ

pipe is termed "the node." It is the point of concussion and recoil. Now, the swing back and forward represents the outgoing of a pulse of rarefaction from the interior of the open pipe, and its return as a pulse of condensation to its blocking position whence it started, the whole time occupied being equal to that taken by the action described in a stopped pipe. In an open pipe there is a nodal point or blocking position a little below its half length, it is the point where the two condensations meet in shock, to be then returned in opposite directions. The organ pipe should be considered as a reciprocating mechanism. The reason for the nodal point being below the half length is that the pulling or outcurving motion occupies more time than the incurving does, and even the reversal of direction of the air-reed takes time, as the drawing the bow is of longer time than the discharge of the arrow. The two movements together make up the time between one shock and the next. A stopped pipe to be unison in pitch with an open one requires in the same degree to be shorter then the half of the open one, for if cut to the exact half it will prove to be a semitone flat. To say that because a pipe is stopped it gives an octave lower note is everyway misleading; it takes the mind away from perception of the true correspondence of the relative conditions, and teachers have to resort to a talk of two condensations and two rarefactions to make up one vibration, unable to show why it should be so. They are seemingly bound by necessity to make a calculation to fit in with a foregone conclusion, quite needlessly.

I hope my explanation will be convincing, and that my new theory of the action of the organ pipe will be accepted as a true reading of nature, of cause and effect.

Sounds made Musical by Pitch.—In order that sound should be musical, it is requisite that the frequencies of vibration, or change of state from momentary vacuum to momentary equilibrium should recur with uniformity in time, and the *time distance* between *two of any series* of shocks or pulses we measure by the second of time, and call it pitch. Be on guard against the common illusion brought about by ways of speech, that a certain number of vibrations make a note, as if, for instance, 512 vibrations were required for treble C—all told, like beads on a string, or pence to a sovereign, no,—remember it is *at the rate of* 512 vibrations per second, or in other words the vibrations should recur at intervals equal to the 512 part of a second ; how many the vibrations are does not in the least matter, it is only the time-distance *between* the shocks that determines pitch, and a very few shocks in succession are quite sufficient for the ears' decision.

The outline sketch which I have given of my theory of the nature of the action taking place in the organ pipe is all that the limit of this book will permit, fuller information may be sought for in my writings on "The Making of Sound," etc.

My theory has been before the musical world for many years, it dates from 1865, and since the incorporation of an account of it in the second edition of Dr. A. J. Ellis's translation of Helmholtz Sensations of Tone it has been favourably acknowledged in some scientific text books on acoustics, and in musical literature, and so far as I have been able to judge has been generally accepted amongst organ-loving people who happen to be curious about the How and the Why. This much I think may fairly be stated lest to some readers it may come as a new thing, and straightway be classed with "other vain imaginings."

143 the bk has no date is shows it pretty old.

SECTION VI.

The Practice of Tuning the Organ.

It takes two men and a boy to tune an organ. One man is required to blow the bellows, and carefully to watch to keep the supply of wind equal, and without jerks; the second man has to find a location somewhere inside the organ; and a boy has to undertake putting down the keys as he is told from time to time, when a voice cries out from above "next," "next." There is a way possible to adopt by which the whole operation of tuning can be accomplished by one man; the tuner will then wedge down a key and its octave key or place a weight upon each to keep it down, then go round or perhaps down to the bellows and fill the reservoir to the utmost; next to rush up into the organ and tune the particular pipe, speaking from the selected key. This, as you may imagine, is a tedious process, and requires that the tuner should be both active and willing; this plan is not advisable, it is good exercise and that is all that can be said in its favour. Nevertheless, on emergency some organists have to follow it when one or two erring pipes, can no longer be tolerated. The correct routine of tuning is for the directing tuner to sit at the keys, and thence give out his instruction to a trusted assistant in the organ, who does the work in the way directed, to obtain the pitch, going from pipe to pipe. In this case it is the tuner at the keys who is responsible, although the man inside the organ may be quite as good a judge of the pitch and the tuning.

The work of the tuner.—It consists in using a solid brass cone to expand the top of a metal pipe when sharpening is necessary, and for the converse effect, a hollow brass cone to contract the rim, so that the edge of the pipe is caused to curve lightly inwards, and this is done to flatten the pitch. Then there are sundry little pieces called shades, of wood or of metal, as the case may be, at the tops or sides of some pipes, and ears at the side of the mouths of some, and there are others with slides over little slots near the top, and a slight variation in the position of any of these pieces suffices to make the trifling change required to bring the pipe to the correct pitch. Opening or giving more freedom to the contents of the pipes tends to sharpen pitch, and closing or contracting an outlet tends to flatten pitch. The stopped pipes are altered by moving the stoppers higher or lower in position, and very often dryness of air causes the stopper to become a little loose, and this has to be carefully looked to, since quality as well as pitch is injured by any lack of tight fitting in the stopper. The reeds are under different conditions, and are tuned by knocking up or down the little tuning wires that are left for the purpose; the wire is crooked or bent to a right angle so that a slight tap with the back of a reed-knife effects the slight movement which is called for. Lifting the tuning wire lengthens the vibrating portion of the brass tongue, causing the pitch to flatten, and *vice versa*, pressing the wire down causes it to cover a further portion of the tongue, and so, shortening its vibrating length, the pitch rises in proportion. There is danger from any but a practised hand meddling with the reeds. The tuner has generally with him several brass cones, some little mops for silencing pipes in the mixtures,

and carries other little incidentals belonging to his calling.

What to do is learnt by practice in the organ factory, or in company with an older or more experienced tuner, and it is long before a learner can be entrusted to see to the tuning on his own responsibility.

Rats, mice, beetles and bats, spiders and sparrows, and choir boys, are the natural enemies of the organ. Clean dirt is not so dirty as soot dirt, or coke dust; which the bellows sends up into the organ, and from which the valves suffer. The pipes have to contend with hassock dust, fluff and feathers, whitewash and plaster flakings, and dead flies and cobwebs, all highly objectionable.

The tuner has to see that there are no obstructions at the foot of the pipe, no dust in the windway or clinging disused cobwebs, for very little of this kind of matter in the wrong place, may have been cause of the pipe going out of tune, and unless dislodged the pipe cannot be relied upon to remain true to pitch.

How long it will take to tune an organ cannot be estimated offhand, it will depend on the size of the organ, and chiefly on what time there is to spare before the train starts. The skill of the tuner is not always the chief factor in the question, often indeed it is the knowledge of what not to do. "Gumption" is a valuable asset in an organ tuner's character.

Experimental Organ Tuning.—The organ does not readily lend itself to experiment, it is too costly an instrument. To learn organ tuning is literally to learn knocking the pipes about first this way and then that, and a learner would not thus be allowed to try his hand; he has in fact to pick up knowledge as he can,

and with little help; the necessary time cannot be at his disposal, nor an organ be left to his treatment. Generally he takes his chances of watching the tuning, as it goes on by older hands in the Factory's tuning room, or when he goes out to assist at churches.

The lack of time, and want of opportunity make the position very trying to a young man who wants to know and would take pains to advance himself. Teaching alone is not sufficient to make a man an adept in organ tuning, he must have experience in handling the pipes, and in doing practical work that is to stand.

Every factory has what is called a tuning machine, that is a small bellows with keyboard and soundboard, on which is mounted a set of pipes, accurately tuned, every one of them at a temperature of 60 Fahrenheit, or it may be that the builder's choice has been at 65 or 68 degrees; whatever it is, *that set of pipes* is the standard by which all the pipes that leave the factory are tuned. For the accommodation of the pipes that have to be tuned there are spare slides and racks. Very obviously such an apparatus is not at the command of every one, and the progress of the ambitious young tuner is slow.

My advice is to procure a small harmonium, and upon that work out the principles of tuning and temperament; for these are the same for all keyboard instruments. The cost is very trifling, in an auction room harmoniums can be bought for very little indeed. A small one will be best, one row of reeds will do, but a two row will give the advantage of keeping one row untouched to compare results by, and the second row be used for trial and experiment to any extent. Never mind spoiling reeds, you want them for that purpose, and

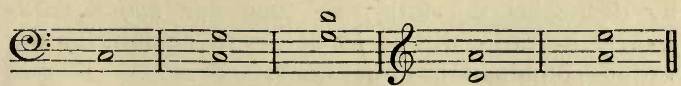
can replace them at about twopence, and less in proportion by the set. Then you will generally find the bellows spring much too strong, making the tone of the reeds hard and jerky, so a spring, an ordinary couch spring, that is lighter should be got, in order that the wind may be steady. With such an instrument the beats come clear and strong upon the ear, you can try all manner of tuning and tempering, and make perfect chords, contrasting them with tempered chords, training your ears to catch the effect of progressive changes under your hands and so learn far more at home than you would with the organ.

SECTION VII.

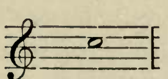
The Scientific Principles of the Theory of Equal Temperament: and the Practice of the Art of Tuning.

Temperament denotes the arrangement of a system of musical sounds by which a minute quantity is abstracted from the original purity or magnitude of some, or most of, the intervals which may be formed by them, in order that *all* the sounds of the system may be so connected as that *each one* may not only form serviceable intervals with all the rest, but also that each one may be employed as the root of a major or minor scale, every note of which shall preserve the due relation of intervals with regard to the rest. This is rendered necessary by the very varied relations in which musical sounds are in modern times required to be employed both in melody and harmony.

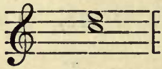
Experience teaches us, and writers on the mathematical theory of sound demonstrate, that if we tune the following series of perfect fifths.



the E last obtained will be found too *sharp* to form a *true* major third to the note



the double octave to the C in the bass, from which we started. Indeed, the third



thus obtained is so sharp as to be utterly offensive to the ear, and therefore unfit for harmony, where this interval plays so conspicuous a part.

To remedy this inconvenience, it becomes necessary to tune each of the fifths a very small degree *flatter* than perfect. The E obtained by this means will not be so sharp as that obtained before ; though if the fifth be properly altered—or *tempered*, as it is termed—it will be somewhat too *sharp* ; as the fifths will not admit of being tuned so flat as to produce a *perfect* major third, without their consonancy being too much affected.

If we continue the above series of *perfect fifths* to B, F♯, C♯, G♯, &c., and compare the notes produced, respectively with the octaves or double octaves of the notes G, D, A, E, &c., before obtained, we shall find the same defect in all the other major thirds. Hence it appears that if we tune by *perfect fifths,* all the major thirds will be so sharp as to be unbearable ; and that if, by depressing the fifths, we tune our *major thirds perfect,* the fifths will be so flat as to be unfit for the various combinations of harmony.

We must, therefore flatten each fifth of the complete circle, C, G, D, A, E, B, F♯, C♯, G♯, or A♭, E♭, B♭, F, C, progressively in a very small degree ; the depression while it will not materially impair the consonancy of the fifths, will produce a series of somewhat sharp, though still agreeable and harmonious, major thirds.

The necessity for *temperament* becomes still more apparent when it is proposed to combine every sound used in music into a connected system, such that each individual sound shall not only form practical intervals with all the other sounds, but also that each sound may be employed as the root of his own major or minor key; and that all the notes necessary to form its scale shall stand in such a relation to each other as to satisfy the ear.

The chief requisites of any system of musical temperament adapted to the purposes of modern music are:—

1. That all *octaves* must remain perfect, each being divided into *twelve semitones*.

2. That each sound of the system may be employed as the root of a major or minor scale, without increasing the number of chords or sounds in the system.

3. That each consonant interval, according to its degree of consonancy shall lose as little of its original purity as possible: so that the ear may still acknowledge it as a perfect or imperfect consonance.

Several ways of adjusting such a system of temperament have been proposed, all of which may be classed either under the head of *equal* or of *unequal* temperament.

The system of *equal* temperament, is that now in general use throughout Europe, and it is only on some ancient organs that mean-tone or other kinds of temperament yet remain as originally disposed.

Mr. W. S. B. Woolhouse remarks truly, "It is very misleading to suppose that the necessity of temperament applies only to instruments which have fixed tones. Singers and performers on perfect instruments must all

temper their intervals, or they could not keep in tune with each other, or even with themselves; and on arriving at the same notes by different routes would be continually finding a want of agreement. The scale of equal temperament obviates all such inconveniences, and continues to be universally accepted with unqualified satisfaction by the most eminent vocalists; and equally so by the most renowned and accomplished performers on stringed instruments, although these instruments are capable of an infinite variety of intonation. The high development of modern instrumental music would not have been possible, and could not have been acquired, without the manifold advantages of the tempered intonation by equal semitones, and it has, in consequence, long become the established basis of tuning."

The demonstrations of the theory.—The ancient musicians, as has been shown, relied upon the ear for accuracy in the pitch of sounds they gave by voice or other instruments. If they had regard to demonstrations of theories entertained, they then resorted to the monochord. Organ builders had their geometrical designs determining the proper relation of lengths of pipes to diameters in laying out their scales of pipes, and in ruling the proportions throughout the octaves with the variations necessary to secure the qualities of tone they desired; their methods, however, were purely empirical. The system was based upon measurement, and the foundation was the footmeasure, which in the different European countries differed very widely. Dr. Ellis names about a dozen in vogue, thus accounting for the want of uniformity in the pitch of continental organs. Father Merseune, 1636, took up the discovery

of Galileo of pitch numbers, and associated it with strings, and was the founder of musical acoustics, and after him a series of great men in that science carried on its development, inventing methods of proof of pitch vibration by mechanical aids. Thus it has come to pass that in our day we refer all matters of pitch to numerical relations of vibrations, and resort to tuning forks as the speediest determinants for every day use.

The tuning fork, originally called the pitch fork, was invented by John Shore, who was Royal Trumpeter in 1711, Sergeant Trumpeter at the entry of George I., 1714, and lutist in the Royal Chapel, 1715. No marble is dedicated to his name, no statue has been set up in his honour, yet surely was he one of the world's true benefactors, and thousands of tuning forks in daily use now throughout the civilized world tell of our great debt to one of the unhonoured.

This is his only epitaph—
He died deranged in 1753.

The Vibrations of Air, or of Fork, or String.—It is only by the aid of scientific instruments that the frequencies of the vibrations have been ascertained. The eye cannot tell anything of these numbers of vibration, nor will the ear detect their numerical succession. A complete swing of a prong of a tuning fork or of a string *to and fro* constitutes one vibration; and these two swings correspond to the one interval between one shock of air and the next shock.

The Determination of Pitch.—What should be the numerical pitch relatively of each note under any chosen pitch has been arrived at by close arithmetical calculations, and not by the exercise of a musical ear, there-

fore there is no room for deviation from an absolute accuracy of demonstration. Forks are made to known standards, tested and marked; and a whole set of thirteen forks accurate to pitch can be had giving each semitone throughout the octave. (Cost, 1s. 6d. each.)

The Problem before the Tuner, although he often does not know it, and goes blindly to work, is after all a problem of ratios—ratios of the so-called consonances or tones that blend into one another.

The Ratios of the Consonances.

The consonances we deal with are the

	Octave.	Fifth.	Fourth.	Major Third.	Minor Third.	Major Sixth.	Minor Sixth.
ratio	$\frac{2}{1}$	$\frac{3}{2}$	$\frac{4}{3}$	$\frac{5}{4}$	$\frac{6}{5}$	$\frac{5}{3}$	$\frac{8}{5}$

These are all the consonant intervals that lie within the compass of the octave.

The Departure from the Ratios.—In tuning these intervals you have to rely entirely upon your ear, and this not to discriminate pitch, but to tell you when they blend, and when and how much they depart from this true blending—that is all; the only absolute consonance is the unison, all other consonances are but consonances in degree. This series of ratios shews that convincingly, and although for convenience we apply the term, yet for true mental perception of facts it should be borne in mind that alike in all, the conformity is one of degree; according to the system of equal temperament which you will have to adopt, it is expedient to depart somewhat from the absolute truth of these ratios in the vibrations of the notes forming these intervals (the two relations, octave and unison, alone

excepted), and the measure of that departure, from the smoothness of the blending in each case, is the degree of roughness apprehended by your ear, and the roughness when it lessens resolves simply into beats, which come upon the sense of hearing like throbs or pulsations. It is quite easy to make clear to you by figures the exact measure of that roughness, and to show you what such degrees of beating or blending should be, in every case, for every interval, as you will presently discover.

The foregoing array of intervals looks portentous of difficulties; but let there not be cause for alarm, since practically all that the tuner has to tune consists (unisons apart) only of the octaves and the fifths, and then the other intervals fall right naturally if these have been tuned accurately. The only stumbling-block you have to get out of your way is that little *if*.

Ancient Determination of Ratios.—From Greece, the seed-plot of all our learning, we derive our system of musical ratios. Long before anything was known of pitch numbers or of means of counting them, Pythagoras, 2,500 years ago, had taught that if a stretched string be divided into two parts by a bridge in such a way as to give two consonant intervals when each part is separately plucked, then the lengths of these parts must be in the ratios of these whole numbers. If the bridge is so placed that two-thirds of the string lie to the right and one-third to the left, so that the two lengths are in the ratio of 2 : 1, they produce the interval of an octave, the greater length giving the deeper tone. Placing the bridge so that three-fifths of the string lie to the right and two-fifths to the left, the ratio of the two lengths is 3 : 2, and the interval is the fifth; and so on, the calculations were carried out for the other intervals.

By modern ways of estimating musical ratios the calculations are by numbers of vibrations of which the ancients had not the knowledge. By means of the ratios of the pitch numbers already assigned for the consonant intervals, it is easy by pursuing these intervals throughout to estimate the ratios for the whole extent of the musical scale; and this is the series for the Diatonic Scale.

Notes	C	D	E	F	G	A	B	C
Ratios	1 :	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
Names	Tonic.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Octave
Vibrations	24	27	30	32	36	40	45	48
Difference		3	3	2	4	4	5	3

The vibrations are stated in the lowest integral numbers; when the vibrations as actually reckoned in our *lowest* musical octave are given, they stand thus in strict ratios:—

	C	D	E	F	G	A	B	C
Vibrations	32	36	40	$42\frac{2}{3}$	48	$53\frac{1}{2}$	60	64

but the fractions do not permit the facility for calculation afforded by the whole numbers above.

Higher numbers might be given, but the result would be the same in each case, since the principle is that two sounds preserve exactly the same distance or interval so long as the vibrations of the two sounds have the same *proportion* to each other.

Now for a little stroke of practice.—Take the tonic number 24 and divide it by any of the lower of the ratio figures, and multiply by the corresponding upper ratio figures, and you will find that they produce the series of figures as stated below each note. Thus, for the fifth

divide 24 by 2, product 12, that multiplied by 3, product 36; and so under G you will find it 36. The result will work out in the same way whatever number is taken as representing C; thus, say pitch C 512, and treat it by the same process. Divide 512 by 2, product 256, and multiply by 3, product 768, which is the number of vibrations for G when it is a perfect fifth to that tonic C. The same process will give you the figures for each note with respect to the other intervals upon the same tonic basis, although you will find a difficulty in dealing with such high figures, because fractions are involved, and you will need to place several decimals in order to approach accuracy, hence we use tables, with appended figures of the vibrations of each note, prepared by experts in logarithms, which can be relied upon in tabulating various scales. At a further stage, when you need them, you will find all the figures tabulated. (See pages of tables inserted).

It is well you should *look into* the simple array of figures now before you, because work is always more likely to be true when the worker knows the reasons for any particular way of procedure, or, in commonplace phrase, "knows what he is driving at"; for if you aim at a target there is more likelihood of hitting somewhat near the centre if a bull's-eye is clearly marked upon it, and when, not left to guess at the centre, you can discern accurately where it is.

The Defect of the Diatonic Scale.

Now to take you a step further.—The state of the intervals, as shown by the ratio figures, is placed before you at this initiatory stage, and claims attention, in order that you may have a clear impression upon your

mind why tuning by tempering is required, why some departure from diatonic accuracy became inevitable when harmony demanded freedom of modulation, whilst retaining fixed tones as on key-board instruments such as we have at the present day.

When examined for the purposes of *harmony*, it is found there exists a notable defect in the untempered diatonic scale, and this fact affords us the simplest way of putting the argument for temperament. When the *differences* marked in the series between the several notes are thought over, it will be at once apparent that difficulties must arise when "*the second*" is taken as the tonic for departure for another octave scale; it will be found rightly, on taking each fifth obtainable within the octave, that C G, and E B, and F C, will by the figures work out in exact accordance with the ratio 2 : 3, but that D A will not—it is considerably too flat for a perfect fifth. Write it out in figures, and you will see plainly how this is: thus, divide the figures under D, 27 by 2, product 13·5, multiply by 3, product 40·5, whereas the actual pitch number found in the scale under A is 40, showing, that being thus deficient, this cannot prove a true fifth to D. Of course the deficiency throws out of relation every other note making an interval with A. Therefore D cannot, unaltered, be taken as a tonic for starting a new octave scale as applied to a key-board instrument. Thus we have seen how the justness of the original scale throws out the justness of another scale of fixed tones. Consequently some way had to be found by which to get out of the difficulty. Voices could modify pitch at will, but hands holding notes tethered for harmony, were obstinately beyond control. Hence various attempts were made from time

to time to adjust the relations of the twelve notes of the chromatic scale to satisfy the growing requirements of the never-ceasing developments of harmony during the last three centuries.

Temperament.—Mean-Tone.

For a long period a system called mean-tone temperament held sway, particularly upon organs, and was only totally abandoned within very recent years. The perfectness of the thirds was then the chief consideration with musicians, the consequence being that the fifths were caused to be very flat, and some were left so intolerably bad that their beatings could only be compared to the howlings of "rampagious wolves," and many poor jokes were perpetrated by old organists at their expense. Some organ tuners now have a hankering after the old system, leaving a wolf now and then, although professing to tune in equal temperament; needless to say, the practice should not be countenanced, it is often only an excuse for slovenliness and the excess is left on the last fifth of the round, to escape the necessity otherwise of going over the work again. On the old mean-tone system it was wholly impossible to play in some keys, the chords became so distracting.

Musicians, after many protests, permitted the general adoption of a newer system which equalized the disturbance, a system which, properly carried out, leaves no wolves—that is to say, no exceptional dissonance in any part of the scale. There is no need to encumber your attention now with the mathematics of the *theory* of temperament, it is sufficient that you should perceive the fact just pointed out, of the flat fifth occurring naturally in the diatonic scale, and how, by reason of

this, a demand for temperament of some sort was not to be avoided. In addition to the fifth D A, you will find that the minor third D F, and the major sixth F D, are alike thrown out of relation when the unaltered D is taken as key-note or tonic instead of C.

The table of ratios already given is incomplete until the minor sixth 5 : 8, and the minor third 5 : 6, are added to the diatonic scale. Upon all the enumerated ratios, the series being now entire, the true arithmetical calculations can be made in strict ratio for all the pitch numbers of the twelve notes in the octave on a keyboard instrument.

Equal Temperament.

Temperament is what the Italians call *participatione*, *participarto*, or *systema temperato;* the diminution of some intervals and the augmentation of others, to produce a more general agreeableness and adaptability for use in every key, major and minor.

Beginning to know.—In equal temperament it is understood that the division of the octave is by twelve perfectly similar intervals, and that the tempering is one of degree, working by *progressions* throughout the octave.

The two cardinal points of the system are :—

1. All octaves shall be tuned perfect.
2. All the fifths shall be a little flatter than perfect.

So you see there is very little to remember. The first it is easy to observe as a rule, and with practice, to carry out ; but the trouble to the beginner is that the octaves may be tuned so as to be beautifully perfect, and yet every fifth may be at the same time deplorably wrong, a discovery that brings the student often to the limit of exhausted patience.

The second instruction is so vague that it amounts to no more than the definition given by the witness, who, asked by the judge what was the size of the stone said to have been thrown, answered, "About the size of a lump of chalk, yer honer." The manuals of instruction seem content to leave each student to make his own guess how much is "*a little*"; then, for further enlightenment, he is told that when he hears "two slow waves" the fifth is properly tuned; this helps the learner but little, since he has no standard by which to judge before he begins.

How can any instruction be reasonably considered adequate that leaves the student tuner in this mental haze? Yet it is the fact that, as a rule, professed tuners can give no clearer account having never troubled themselves to arrive at exactness of definition, but, having acquired skill to judge "how much" and "how slow," they are content to leave the matter that others may find out, as they have done, by practice.

Another error equally common, that the tuner labours under, is the belief that he tunes all his fifths equally flat, and all his fourths in the same octave equally sharp; here he deceives himself, else in the nature of things he could not have brought his work to the satisfactory condition that attests his skill. The tuner is dealing with vibrations he cannot count, with ratios he does not understand nor cares to, and, when questioned, he almost resents the implied suspicion that he does not know his business. The aptness of skill possessed by a man often leads him to despise scientific knowledge and scorn inquirers.

Tuning is Rectification of Numbers.—It cannot be too forcibly impressed upon the mind that the tuner is

dealing with numbers, numbers of minute shocks upon the ear, which take place within brief periods of time. Thus, say 512 shocks following one another with such rapidity that the ear has received that number in succession within the space of one second of time. "Well," it may be remarked, "what has the tuner to do with that? It is a bit of scientific talk, nothing more, it is not practical." The rejoinder is, that indeed it is the only thing that is practical, both in action and indication; the excess or lack of a particular number of these shocks easily ascertained, is the only knowledge you can have of the effect of your work as a tuner.

Reason it out and bring home the proof personally. Take, for instance, the unison notes to middle C; suppose your task is to bring two non-agreeing pipes to give one sound, called *the unison*, that being two sounds brought to unity of effect upon the ear. Suppose next that one of these two pipes agrees as an octave with the standard pipe, and being, therefore, an octave lower than 512 gives its swings at half the rate, viz., 256 per second, which is the proper pitch number, the second of these two pipes being out of tune to its fellow, gives—well, you know not what number of vibrations, only that it disagrees; but in consequence of its position it is to be assumed that it approximates to the desired pitch, and you set about bringing it into unisonal agreement. It may be that you cannot tell really whether the pipe to be operated upon is the flatter or the sharper of the two. However, the least approach of the hand to the mouth of one pipe suffices to make that known when the pipes are sounding; because, if by that approach ever so minutely the dissonance increases, it is evident that the

reverse action is the right way of operating towards agreement. Probably the pipe, let us say for illustration, vibrates only at the rate of 252 vibrations per second, and gradually you, by the cone or the slot bring it to pitch until the two sounds blend perfectly into one.

Now, seriously consider, what is it that this condition gives assurance of concerning your operation? Why simply this one fact, and nothing more, that you have caused that pipe to increase its pace; and whereas it gave four vibrations less, and so disturbed the ear, it now gives 256 exactly, no less, no more, and for that reason it is that the two sound smoothly and pleasantly. If it had been increased to but 257, that one would have told you so, and said "One," and that is the only announcement it would have made, for you would have heard an *unpleasant beat or throb* once in every second; if 258, there would then have been two beats in that time, and so on; and in like manner, if, instead of there being an excess in number of the vibrations, there had been deficiency, the one or two less would have tapped you on the ear, and made disturbance until attended to and rectified. Take the illustration home to yourself as a personal experience, and you will recognize how it is numbers, and numbers alone, that you are dealing with.

So the whole tuning of an organ resolves itself into numerical relations, for what is true of one pipe is true of the whole range of the compass; and thus the consonance and dissonance between intervals great and small are similarly dependent upon the demands of the ratios of numbers.

The Beats are the only Guide.

Beats announce the degree of departure from the exactness or truth of ratios. We are now prepared to pursue the inquiry to the inter-related details of the several intervals, in so far as may be of interest for the full understanding of attunement and mistunement.

That the Octaves shall be perfect is as the law of the Medes and Persians, which altereth not. The octave and the unison are the consonances that the ear will not allow to be in any degree tampered with in tuning.

The Adjustment of the Fifth.—The fifth is an interval that, of all others, will the least bear being disturbed in harmony, and even in melodic relation it is keenly judged. By actual experiments carried on by Dr. W. Preyer it was found that human ears recognize the relationship of the two notes comprising a fifth better than any other relationship between two consecutive notes.

The easiest natural rising of the voice is the interval of the fourth, for the fifth demands effort; and on account of the effort, the ear more readily judges the effect obtained, in the same way that the eye recognizes actual design. In calling to a friend at a little distance the voice naturally in the effort rises to the fifth, whilst the inflexion of the fourth is common in ordinary conversation. Design implies some intent of accuracy in result; hence a fifth bears with it a demand for attention, and the ear, in its sensitiveness, is annoyed where there is emphasized departure from accuracy. Also the fifth is relatively the slowest beating interval under equal temperament, and the beating is so pronounced that, when over-increased, it forces itself upon the attention. Consequently you will understand how very carefully such intervals have to be adjusted.

The Succession of the Fifths.—The system of tuning is based upon the succession of the fifths in a series called the circle of fifths; and the tuner adopts a method which brings the series within the one central octave. The beautiful simplicity of it is, that in the result, the fourths and every other interval will be found to have been tuned simultaneously upon the completion of this circle. If the tuning is accurate, the tuner upon this system need take no care of the lesser intervals; yet in practice, as you will learn, he tests by these on the way, in order to judge of the correctness of each step taken. Although in equal temperament we cannot have perfect fifths, still they are very considerably better than those which musicians had to put up with under the old mean-tone system. Since all the fifths are required to be a little flatter than perfect, it is highly desirable that you should obtain some surety in procedure, some direction or guidance as to the interpretation of the word "little," which otherwise would be the synonym of endless fog for the unpractised. If the doctor told his patient to take a little strychnine for his health's sake, the point upon which the patient might be anxious would be, how much is a little?

How flat is a little flat?—Figures will soon solve that problem for you. At Standard pitch the D above mid C, with its fifth A above, should under equal temperament depart from the true concord to very nearly one beat in one second of time. How are you to know that this is a true conclusion? You can demonstrate it to yourself by the simplest use of figures. But meantime another question crops up, How to estimate the *second?* for when there is no clock ticking seconds in the room, and if you have no seconds-hands stop-watch to hang

up for visible indication of the fraction of time entering into the problem, you are left to guess at it.

A Home-made Pendulum.—You can readily provide yourself with an unerring pendulum. In this way: take a yard or so of thread, tie one end to a ring, or shut it fast in a pill-box, or fix it to a bullet or other trifle to act as a weight, then from the *centre* of such ring, box, or bullet, measure a distance of $9\frac{7}{8}$ inches, and at that length wind the remainder of the thread and you will have a freely suspended pendulum $9\frac{7}{8}$ inches long, whose swing will in its to and fro movement exactly occupy one second of time; and by the unvariable law of the pendulum these double swings, whether they are performed through large arcs or small, will be precisely the same in time, as true to the second when the force or extent of the swing is diminishing as at starting. Here, then, is a sure guide.

Set the pendulum swinging, and accustom yourself to its pace, in this way, saying deliberately—one—and,—two—and,—three—and,—and so on up to ten, and then begin again at one, and six of these tens will make one minute—the *and* always to coincide with the starting of the swing to the right, and the *number* with the commencement of the swing from the left, or *vice versâ*. It is the double swing that constitutes the second; the Germans call it the swing-swang. After a little practice you will be able to calculate, anywhere, a series of sixty seconds, comparing your *pace of speaking* with the minutes recorded on clock or watch. Having acquired this habit of judging the length of a second, you can dispense with the pendulum if you like, and go confidently to work, secure of your standard of a second of time.

How the rate of beating is calculated for each interval.—Now resuming the figure details, and calculating on the following method in actual number of vibrations, we can ascertain for every interval to a fraction what the *beating rates* should be on an equal tempered scale.

When mid C is 256, the D next to it is in pitch at the rate 287·35 vibrations per second, and its fifth above, which is A is 430·54. The ratio of a fifth being $\frac{3}{2}$, multiply 287·35 by 3, product 862·05, and 430·54 by 2, product 861·08; the notes of the interval, therefore, show a difference, ·97, as you see, the A is almost one vibration flat. The ratio of the concord is thus disturbed in the near relation of one beat in one second of time.

Are all Fifths to beat the same?—Certainly not, if you work accurately. Let us examine a fifth standing a little higher. Take the mid fifth, F to C above; the table of the vibrations at pitch standard gives F 341·72, and the treble C 512, now multiply 341·72 by 3, product 1025·16 and multiply 512 by 2, product 1024; showing that this fifth is flat by 1·16 vibration in one second; take a higher fifth, G 383·57, multiply by 3, product 1150·71; then D above which is 574·70, multiply by 2, product 1149·40; showing that the fifth is flat by 1·31 vibration in one second, so that the rate of the beating increases regularly for each higher fifth.

Carrying the trial to the octave the absolute rule is that the number of vibrations double: so D 574·70 multiply by 3, product 1724·10, and higher A is 861·08 multiply by 2, product 1722·16; proving that this fifth will inevitably produce two beats in the time our first fifth produced one, its beat is 1·94; within the octave step by step every fifth is progressively a faster-beating fifth, and for every other interval the same reasoning

holds. This is an important truth, the statement of a law from which there is no escaping. All the blandishments of a tuner's self-satisfaction are of no avail against scientific verities; he may as well dispute the propositions in Euclid.

Comparative frequencies of vibration.—At this stage of the elucidation, the following tables of vibrations of the Diatonic scale and the Tempered scale may be usefully compared: the intercalated C's are 64, 128, 256, but selecting the figures four octaves higher will show the differences more strikingly:—

Diatonic.		Tempered.	Diatonic.		Tempered.
C	32	32	C	512	512
D	36	35·92	D	576	574·70
E	40	40·32	E	640	645·08
F	42·66	42·71	F	682·66	683·44
G	48	47·95	G	768	767·13
A	53·33	53·82	A	853·33	861·08
B	60	60·41	B	960	966·53

The C here is taken at 32 vibrations, which, reduced to lower octaves, is 16, 8, 4, 2; this power of 2 perpetually doubled leads up to 512, and is accepted generally as the philosophic basis in calculation, and is in every way more convenient than the fluctuating standards which in their caprice musicians adopt from time to time.

It seems probable that C 510 was the actual working pitch in Handel's orchestra, for his A tuning fork gives vibrations 422·5, which would make C 507, and the rise in temperature in a building would soon place the orchestral wind instruments and the organ at 512.

The most accurate table with decimals known to me is that set out in the little "Treatise on Musical Inter-

vals," &c., by the late W. S. B. Woolhouse, F.R.A.S., whose mathematical powers are so well-known that any such work from his hands may be held to be authoritative (published by C. W., 174, Wardour Street).

The tables are given in the four octaves within which the ratios of intervals are usually to be calculated, and when lower notes need to be reckoned all that is necessary is to halve the figures, which will give the lower octave. The figures are for the scale of equal temperament at the Philosophical Pitch.

TABLES OF VIBRATIONS PER SECOND.

C	128	256	512	1024
C♯	135·61	271·22	542·44	1084·89
D	143·68	287·35	574·70	1149·40
D♯	152·22	304·44	608·87	1217·75
E	161·27	322·54	645·08	2090·16
F	170·86	341·72	683·44	1366·87
F♯	181·02	362·04	724·08	1448·15
G	191·78	383·57	767·13	1534·27
G♯	203·19	406·37	812·75	1625·50
A	215·27	430·54	861·08	1722·16
A♯	228·07	456·14	912·28	1824·56
B	241·63	483·26	966·53	1933·06
C	256	512	1024	2048

I have chosen this table because I know of no other table calculated at other pitches that will work out in all its relations so accurately as this. With a little attention you will not get confused by the decimals.

Convenience of the Philosophical Standard.—As, upon this basis, with the C 512, the fractions in the various relations of numbers work out more closely than upon a tonic otherwise chosen, we may whenever we have to make tuning calculations, accept C 512 as doing duty for the Normal Pitch C 517·8, the beating difference it causes being very small.

When dealing with an organ or instrument kept to the High Pitch C 540, which as you will observe is nearly one semitone sharp, we have only for actual use to consider C♯ 542·44 in the same table, as acting for C 540, since the difference may be regarded as practically unimportant, and inappreciable in its effect upon our conclusions; the other notes to be similarly advanced a semitone.

To temper is therefore to mistune, with the consequence that all intervals mistuned produce beats which according to their degree disturb the ear: so the beats can be made use of to test the amount of departure from exactitude of interval which under equal temperament is to be admitted.

The tempered concords or mistuned consonances stand in this relation:—

Intervals flattened.	*Intervals sharpened.*
The Fifth, slightly.	The Fourth slightly.
The Minor Third, considerably.	The Major Third, greatly.
The Minor Sixth, considerably.	The Major Sixth, greatly.

WHAT THE NUMBERS OF THE BEATS SHOULD BE.

Proofs of the precise number of beats.—The stage now arrived at is one where the student will ask for proofs of

what the precise numbers of beats should be in the various intervals of a properly tempered scale in the procession of its pitch vibrations. The amount of the beats should differentiate with a progressive increment throughout the octave, so graduated by increase, step by step, as to eventuate in a doubling of the beats on any interval upon reaching the octave position of such interval.

Thus if D A has one beat per second, then D A an octave higher will have two beats per second, and at an octave higher will have four beats per second, and so on. When the vibrations double the beats double. Having a table of vibrations, we can set to work to ascertain the relative beats between any two sets of figures. It is the simplest of arithmetical exercise, one which it is desirable you should undertake, as it impresses the mind so much more forcibly than does the mere acceptance of results.

THE MINOR INTERVALS TEST THE TRUTH OF OCTAVES.

What have I to look for?—Faraday was wont to say, when any new matter for investigation was brought before him for his opinion, "Tell me what I have to look for?" and believing with him that it saves much time if one knows at the first what to look for, this is the knowledge which a careful observation of these figures should force upon you, viz., the fact that the minor intervals can always be made to serve to test the truth, or, in other words, the *exactitude of the tuning of the octaves.* This is a fact worth knowing, and it is by figures that it is to be incontestably proved; and further, as affecting musical theories, we learn that the

fourth, which is termed "perfect," should be called a minor fifth, since by analogy, and properly estimated according to nature's evidence, that is what it is, for it fulfils the same office as do the minor third and the minor sixth in balancing the octave. This will be clear to you as you go on, and will give a new interest to the calculations.

When an octave is divided into two parts by an interposed note of the scale, forming then two distinct intervals, it is and must be divided unequally, for if a major interval exists in the lower portion, then a minor interval occupies the upper portion, and *vice versâ.* We therefore have pairs of intervals, differing according to whether the major or minor of the two happens to be the lower interval of the pair. That, as a proposition, is simple enough. Another fact of interest also you will arrive at upon close investigation.

There are only two relations of beats.—It is curious that in forming these intervals whatever the division of the octave may be, and however varied the degrees of differences in the roughnesses affecting the ear, and however great the complexity of relations may be supposed to be, the plain fact is that only two proportional relations of beats are manifested. Remember that we are dealing with tempered intervals, and the beats are the result of the tempering, since there would be no perceptible beats when an actually perfect fifth or fourth was interposed in an octave that was absolutely perfect. Few persons possess a musical ear sufficiently acute to tell whether an octave as tuned is absolutely perfect—it is strange, but true; clever tuners are often at fault in this particular, and are not a little astonished when challenged, and, by the test

which I am about to bring before you, are proved to have been in error, and the infallibility in which they have believed as unassailable, vanishes under nature's analysis.

EXAMPLES.

Proof.—When an octave is divided into two intervals by a note that has been tempered, if the lower interval is *minor*, then the major interval which is above will beat at precisely *the same* rate. If it does not, then the octave is proved *by that* to be untrue, thus :—

Minor interval. Fourth.	Major interval. Fifth.
C to......................F	to..............................C.
beats 2	2

Proof.—When the lower is *major*, then the beats in the minor interval which is above, *are twice* as many as the beats produced by the lower major interval, thus :—

Major interval. Fifth.	Minor interval. Fourth.
C to............................G	to...................C.
beats 2	4

These are invariable results, whatever may be the extent of the mistuning of fourth or fifth ; if much out of true ratio, the beats in a second are increased, but the proportional relation is maintained in each case the same.

See how very important as a guide this test is, for if the octave is in the least degree greater or less than perfect, then the beats will exactly in such degree depart from agreement with these laws, which the octave invariably obeys if it is really true. Of the least

degree of error you are instantly made aware, and are told whether the error is in flatness or sharpness to the pitch it should accord with, because by using a minor interval for the lower position you possess a pivot upon which the octave finds its true balance, and your ear tells at once whether the disagreeing is by excess or deficiency. Thus, saying that the lowest C is already correctly at pitch, then whatever the rate of beating is shown between C and F, that same rate should be heard in beats between F and C in the upper interval; if the beats are in excess, you will have to sharpen the upper C, thus widening the fifth; and when the two intervals are brought to complete accord, you may be quite sure then that the octave is indeed absolutely perfect and true. The correctness in itself of the fourth or fifth as a *tempered* note, or the rate of beating due to its position in the compass of the keys, this proceeding does not guarantee; but it will often make you aware of unsuspected deviation, which it may be necessary to correct before advancing further.

All minor intervals in lower position balance the Octave.—The test is equally true and valid with all the minor intervals, for the fourth, as above considered, is a minor interval whatever its position. By analogy we may term the fifth *major*, and the fourth *minor* fifth.

Let it be remarked that throughout these demonstrations the signature of the ♭ is dispensed with, and the technical usage is followed of D♯ standing for E♭, and G♯ for A♭, also that the intervals are named by their philosophical recognitions, irrespective of the rule under received systems of harmony which are not here in question.

Minor Intervals.		*Major Intervals.*
C Minor Third	D♯	Major Sixth C
14	Λ	14
C Minor Fifth	F	Major Fifth C
1	Λ	1
C Minor Sixth	G♯	Major Third C
16	Λ	

These beats in each instance balance—they stand in the relation of *unison*. That is the *first* relation.

All Major Intervals beat half to Upper Minors.—The major intervals, when they occupy the lower position within the octave, do not afford the same facility for use as tests; but they are as inflexibly true to the law which governs them, which is that the beats produced by such two intervals occupying the octave stand in the relation 1 : 2, that is, the upper interval beats twice as fast as the lower interval, thus :—

Major Intervals.		*Minor Intervals.*
C Major Third	E	Minor Sixth C
10	Λ	20
C Major Fifth	G	Minor Fifth C
1	Λ	2
C Major Sixth	A	Minor Third C
12	Λ	24

The one set beating double that of the other, the beats therefore stand in the relation of octaves to each other, and this is the *second* kind of relation.

The stated numbers are given only as examples; when we come to calculate precise figures of vibrations as in our table, the beats, whatever they may be, will work out exactly in the proportions set forth, and in no other: there is no deviation from this law. The simplicity of these laws is very beautiful, and wonder-

fully helps us in understanding the impressions made upon us by chords in all their changed relations in harmony.

When you know the number of the beats of one of the two intervals dividing an octave, then the number in the other is directly calculable.

It is necessary to guard yourself against the conclusion that the *actual* number of beats and the *perceived* degrees of roughness have coinciding index of relations; the results, in fact, depend upon the *intensities* of the mingling harmonics. Thus, minor thirds and sixths, always sound *smoother* than major thirds and sixths, although, as above seen, the minor third, C D♯, beats 14, and the major third, C E, beats 10, and the minor sixth, C G♯, beats 16, and the major sixth, C A, beats 12. Musical acoustics will explain how this arises.

The Fourth is the Umpire of the Octave.—For practical value in tuning, the fourth stands out very prominently; the other minor intervals are comparatively very rough, and beyond counting, although affording good estimates by which their condition may be judged. Yet it is the fourth that is the valuable aid, and we find it in a most useful position near the centre of the keyboard, beating under equal temperament one per second, and in its higher octave two per second. These beats are after practice readily perceived and counted; and you should, therefore, never lose dependence on this important aid to the accuracy which every true workman desires. But as you proceed in tuning, test every octave by this interval; for of a verity the fourth is the umpire of the octave.

It may be difficult to the unpractised ear to catch these slow beats at first; but when once they have been thoroughly recognised, the perception of them becomes a habit, and their presence is distinctly marked.

Now these are the time relations of the beats for the tempered fourths in a progressive series throughout the octave, when the tuning is truly carried out as of equal temperament. Do not forget that we can by choice take the C♯ of the philosophical pitch to stand for C 540. This C♯ being 542·44 vibrations per second, is so near to C 540, that for all practical purposes the working out will be the same; and so when the table of vibrations is for working purposes used for High pitch, all notes are taken a semi-tone advanced.

It is not supposed that the tuner is able to reckon these several fractions by ear or knowledge; but the value of the table is in showing him how surely the rapidity of the beat increases at every advancing step in the scale. And he will know that he must so regulate his work as to attain in a general way a correspondence with the rate of rise in the beatings which the table demonstrates as according to the natural law. The tables of the beats of the tempered concords are here inserted and invite study in their varied relations. (See the page of the tables inserted).

As regards the thirds under the system of equal temperament, three tempered major thirds complete the octave. The tables set out the beats of these as follows. Beats per second:—

Mid C with E	10·16	
		—2·60 diff.
E with G♯	12·76	
		—3·41 diff.
G♯ with C	16·17	
		—4·15 diff.
Treble C with E	20·32	
	10·16	

Beats are under the same rule as the vibrations; they for all intervals are, at the octave, doubled in number. Here the difference between 10·16 and 20·32 is 10·16; and, as is clearly shown, the sum of the beats of the three intervals exactly coincides with the octave difference. In the same way take the four minor thirds tempered:—

Mid C with D♯	13·82	
		—2·59 diff.
D♯ with F♯	16·41	
		—3·13 diff.
F♯ with A	19·54	
		—3·70 diff.
A with C	23·24	
		—4·40 diff.
Treble C with D♯	27·64	——
		13·82

As all the intervals were calculated independently, this summing up of the beats is very good evidence of the correct distribution of the beats relatively through the octave. Beats are not countable even by well practised ears beyond about five per second; therefore we rely upon the fourths and fifths to be the safe guides in laying the bearings for tuning. When the beats aggregate in higher numbers the ear judges of them only as of degrees of roughness; higher still the roughnesses become finer and finer and at last vanish altogether.

These tabular views are highly useful, they place before the eye sureties for the belief in the progression of the beats, and in other proportions that have been brought forward in this exposition. To deal with the figures relating to fourths and fifths—take A with D in

the column of fourths, beats per second 0·97—then look down column of fifths for the fifth D—A, you find it, beats 0·97. Minor thirds with major sixths, show the same equal balance. Similarly it is found that major intervals beat half to upper minors—take major third E with G♯, beats 12·8, then find its minor complement G♯ with E, beats 25·6, and so on with all such relations.

Another question is, how the fifth stands in relation to its intervening fourth? Here the figures will tell you, that C with its fifth G, has a beat 0·87 flat, whilst C with its fourth F is 1·16 sharp, and examining further you will see that the numbers bears a relation of 3 to 4—thus, divide 0·87 by 3, giving 0·29, add this part to the original, making 4 parts, product 1·16. Now this rule as to the intervening fourth is invariable. In trial with some of the numbers you may find a little inexactness, but this is unavoidable, unless the figures are such as are easily divisable without remainders, or unless worked out fully with decimals.

Looking at the table, another curious relation I discover concerning the thirds; you will find that the figures shew very nearly a 3 to 4 proportion; so also the minor sixths within the major sixths are very close upon a relation of 3 to 2, all through the scale.

Beats, like vibrations, being exactly doubled at the octave, all ascent is proportional; the first *fourth* of the series, C 256 with F, beats at more than one per second, by sixteen parts out of a hundred; then observe that F A♯ is just a little more than at the rate of one and a half beats per second; and the last, C F, is nearly at the rate of 2⅓ beats per second, or 7 beats in 3 seconds. Of course there is no such thing as beating the sixteen-

hundredth part of a beat, it is a time-relation only, and literally we mean that the *time-distance* between two beats is less than one second by sixteen hundredths of a second, and this is represented by the figures 1·16—that is to say, that one beat's and the sixteen hundredths of the next beat's time-distance would be necessary to make up or equal the time-distance between one second's beginning and the next second's beginning.

So there are no fractions of beats, just as there are actually no fractions of vibrations, only that for our convenience we set down fractions, yet rightly only mean, provided we truly understand the physical relations we are talking about, that in the portion of time we fix upon for our standard of comparison—which in these instances is one second—the number of beats, or, in the case of vibrations, the number of vibrations, happens not exactly to coincide by some greater or lesser fraction with the time specified.

Seek for the Fourth that beats once per second.—If we seek for a fourth, the beats of which exactly occur at the time-distance of one second, it is not to be found. Look now over the table, the nearest to be found is 1·03, which, taken an octave higher, will be 2·06, and will for the moment suit our purpose, the higher figures being preferable in calculating fractions, since for strict working out of ratios it is sometimes necessary to carry the decimals out to three or more figures, which should be remembered whenever discrepancies show themselves, seemingly discrediting the law of ratios. In a general way the variation from accuracy is not of sufficient importance to influence the practical result.

Having, in the pendulum now at your command, a true standard by which to estimate beats, and thereby

to regulate your proceedings, it is naturally desired to find the interval most nearly corresponding in its beating to one second of the pendulum.

As an exercise in figures, choose two of the fourths, one says 2·06, the next lower in scale says 1·94, which taken at the octave lower, will be 1·03 and ·97, the last being 3 below the 100, or unity, and the former 3 above unity; as a matter of figures, the beating of the ·97 being really wider than the second, and the 1·03 narrower than a second as a question of time-distance—understand that—it is a trifle quicker than the pendulum second is. Choosing the latter we find it :—

A . . . D♯ 2·06.

and now find the figures (see table inserted).

A♯ 456·14 the fourth being D♯ 608·87

$$\begin{array}{ccc} 4 & & 3 \\ \hline 1824{\cdot}56 & \text{ratio } \tfrac{4}{3} & 1826{\cdot}61 \\ & & 1824{\cdot}56 \\ \hline & \text{beating sharp} & 2{\cdot}05 \end{array}$$

This fourth takes us out of the tuning octave some commence operations in. So we have to go lower than mid C to find the note we are in want of. The figures can be obtained at once by halving, thus :—

$$\begin{array}{ccc} \text{A}\sharp\ 228{\cdot}07 & & \text{D}\sharp\ 304{\cdot}44 \\ 4 & & 3 \\ \hline 912{\cdot}28 & & 913{\cdot}32 \\ & & 912{\cdot}28 \\ \hline & \text{beating sharp} & 1{\cdot}04 \end{array}$$

This now is an interesting illustration, for the result does not come out correctly as expected, yet I have

taken the figures from the table. A little reflection will show the source of the error, for the half of 608·87 should be given as 304·43½; but the custom is to treat the half of ·87 either as ·44 or ·43, and you should note how it affects results when the decimals are not more fully carried out. It is well to be thus put on guard against hasty conclusions. Reckoning as—

D♯ 304·43	and again	D♯ 304·435 (·870)
3		3
913·29		913·305
A♯ 912·28		A♯ 912·28-
beating sharp 1·01		beating sharp 1·02

The last, you see, more complete in decimals, does bring the result very close, and it shows the importance of elaborateness when there is any misgiving of the invariability of natural law.

Thus it has been proved beyond doubt that A below mid C, and D above, constitute a fourth, beating just within the time-distance of one second, when it is properly mistuned under equal temperament; and for practical purposes this fourth may be accepted as the standard fourth beating one per second. When the pitch is C 512, then the beating of this fourth is less by 3-100ths than the time of one second, its figures being but 0·97; when the pitch is at C 528, then its figures are 0·99. And calculating at high pitch as giving the figures 1·02, the differences are really only perceptible as the finest of differences in a series of every minute gradations, and in no way affect our acceptance of this as a standard. We have merely to remember that it is in each case a shade slower, according as the tuning pitch

Tabular View throughout the Octave of

THE PROGRESSION OF THE BEATS OF THE THIRDS AND SIXTHS IN EQUAL TEMPERAMENT.

COMPLEMENTAL RATIOS OF THE PERFECT CONCORDS

Minor Third. Major Sixth. Major Third. Minor Sixth.

$\frac{6}{5}$: $\frac{5}{3}$ $\frac{5}{4}$: $\frac{8}{5}$

	Per sec. Minor Thirds beat flat			Major Thirds beat sharp				Per sec. Minor Sixth beat flat			Major Sixths beat sharp		
A	with	C	11·6	with	C♯	8·5	A	with	F	13·6	with	F♯	9·8
A	„	C♯	12·3	„	D	9·0	A♯	„	F♯	14·4	„	G	10·4
B	„	D	13·0	„	D♯	9·6	B	„	G	15·2	„	G♯	11·0
C	„	D♯	13·8	„	E	10·1	C	„	G♯	16·1	„	A	11·6
C♯	„	E	14·6	„	F	10·7	C♯	„	A	17·0	„	A♯	12·3
D	„	F	15·5	„	F♯	11·4	D	„	A♯	18·1	„	B	13·0
D♯	„	F♯	16·4	„	G	12·1	D♯	„	B	19·2	„	C	13·8
E	„	G	17·4	„	G♯	12·8	E	„	C	20·3	„	C♯	14·6
F	„	G♯	18·5	„	A	13·6	F	„	C♯	21·4	„	D	15·5
F♯	„	A	19·5	„	A♯	14·4	F♯	„	D	22·8	„	D♯	16·4
G	„	A♯	20·7	„	B	15·2	G	„	D♯	24·2	„	E	17·4
G♯	„	B	22·0	„	C	16·1	G	„	E	25·6	„	F	18·5
A	„	C	23·2	„	C♯	17·0	A	„	F	27·2	„	F♯	19·5
A♯	„	C♯	24·6	„	D	18·1	A♯	„	F♯	28·8	„	G	20·7
B	„	D	26·1	„	D♯	19·2	B	„	G	30·4	„	G♯	22·0
C	„	D♯	27·6	„	E	20·2	C	„	G♯	32·2	„	A	23·2

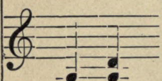
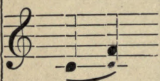
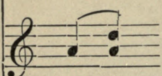
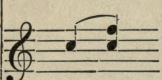
Hermann Smith's "Modern Organ Tuning."

Tabular View throughout the Octave of

THE PROGRESSION OF THE BEATS OF THE FOURTHS AND FIFTHS IN EQUAL TEMPERAMENT.

COMPLEMENTAL RATIOS OF THE PERFECT CONCORDS } Fourth. $\frac{4}{3}$: $\frac{3}{2}$ Fifth.

Relatively the Fourth is the minor to the Fifth.

	215·27	Per second Fourth beats sharp		215·7	Per second Fifth beats flat	
	A	with D	0·97	A	with E	0·73
	A♯	,, D♯	1·03	A♯	,, F	0·77
	B	,, E	1·09	B	,, F♯	0·82
	C	,, F	1·16	C	,, G	0·87
	C♯	,, F♯	1·23	C♯	,, G♯	0·92
	D	,, G	1·30	D	,, A	0·97
	D♯	,, G♯	1·38	D♯	,, A♯	1·03
	E	,, A	1·46	E	,, B	1·09
	F	,, A♯	1·54	F	,, C	1·16
	F♯	,, B	1·64	F♯	,, C♯	1·23
	G	,, C	1·74	G	,, D	1·30
	G♯	,, C♯	1·84	G♯	,, D♯	1·38
	A	,, D	1·94	A	,, E	1·46
	A♯	,, D♯	2·06	A♯	,, F	1·54
	B	,, E	2·18	B	,, F♯	1·64
	C	512 ,, F	2·32	C	512 ,, G	1·74

adopted is lower. The range may be between C 512 and C 540 for choice, and anywhere that fourth will answer the purpose for which we select it.

The fifth above a fourth beats the same as the fourth when it completes an octave. If the octave is a true octave, the beats of a fifth in this position will be exactly at the same time distance from one another as the beats of the fourth below it are.

Guard yourself against the mistake so common among tuners of supposing that the fourth *lying within the fifth* should be as much sharp as that fifth is flat. It is quite erroneous to believe that the fourth C—F should beat only the same as C—G as a fifth does.

Mid C—F fourth should beat	1·16	per second,	sharp.
C—G fifth	,,	0·87	,,	flat.

Again, where the tuner gets his first G *downwards*, about which as his starting-point in the series he is so particular, and then takes his upward fifth, G—D, there cannot be the equality in beating he assumes, except by favouring, instead of adhering to the true relation in tempering. It may please, but it is wrong; correctly—

G—C fourth beats 0·87 sharp.
G—D fifth ,, 0·65·5 flat.

The value of the numerical calculations you have gone through is in the precision of thought acquired by comprehending how Nature really works, and in the reliance you have thereafter in unchanging laws.

Beats what are they?—Beats are phenomena which, in scientific consideration, are regarded as produced by *interference*. For the explanation of this term books on acoustics need to be consulted, but briefly it may be stated that beating takes place between two notes which

depart from true ratios; that is to say, whose coincidences of vibration are imperfect. The beats originate in the very slight perturbations of the periodic coincidences which characterize true concord; then the vibrations of one of the notes gain upon the vibrations of the other, or lose, as the case may be. The limit of beats that are countable is about five or six per second, beyond that the beats are recognizable merely as degrees of roughness, or perturbation. When two notes, having vibrations 500 per second and 501 per second respectively, are sounded together, then once per second only will there be *absolute coincidence*, and all other vibrations occurring between will not exactly coincide; consequently there will be an alternate increase and diminution of the combined volume of sound. Midway in the second of time an interference or a neutralization of sound takes place, so that beats are the expression of continuous variations of intensity of the compound sound.

We hear a series of bursts of sound, with intervals of comparative silence between. The emphatic periods of absolute coincidence are the times of the beats, with a doubling of the intensity of the volume of sound for that brief instant. In the case above named the time-distance between one beat and the next that arrives is the 500th part of a second. It is a common occurrence to find yard tape measures not quite true; one will measure an eighth or more less or in excess. Now if you compare these as to the various marks of division, you will notice how there is in minute degree constant *difference*, which accumulates at each successive inch, either indicating extension or contraction of measure. Now supposing it was possible uniformly to stretch the shorter yard, or to squeeze the yard, an eighth more, to the

length of a true yard, you would gain a very good representation of this beat phenomenon; the one instance being of imperfect coincidences in the lineal spacings, and the other imperfect coincidences in the time spacings. How interference arises in the wave-motion of air under sound pulsations is, as I have said, matter for another course of study.

How about Vibrations?—The idea of time-distance you must also import into all questions concerning vibrations. In the ordinary and orthodox fashion, I have been speaking of vibrations as so many in number per second. It is commonly affirmed and believed by musicians that the pitch of a note is determined by a specific number of vibrations; thus, that treble C is constituted by 512 vibrations in one second of time. And it seems to be accepted literally that, until that number is fully made up, all told, the ear can have no perception of the existence of that said note, treble C. It is spoken about just with the same inference as that twenty shillings go to the sovereign, or as in a tale of beads or a gross of screws 144 makes one gross; and until that number is made up, the gross cannot be said to exist. The phrase unfortunately leads to a total misconception, for the idea gets a lodgment in the brain, and without thinking is accepted as true.

Now, I ought not to say even that 512 pulses, or shocks, or vibrations will constitute that note C, or speak of any note with similar inference of numbers, and, indeed, I have unwillingly followed the usual way of speaking only because of fearing to confuse you by a novel way of definition.

But, in truth, it is not number collectively that rules. All that is necessary is that there should be two con-

secutive pulses following at the time-distance equal only to the 512th part of a second of time—and this is a very different kind of proposition; so that properly one should say that vibrations are at *the rate of* such a number per second: all that the ear requires is that there shall be a sufficient number of these pulses in succession to give the ear a sense of continuity, nothing more. Continuity for the eightieth part of a second would enable the ear to recognise the note C of that stated pitch; yet if we had the alertness of perception, with a due sensitiveness of the nerve power in audition, two pulses as efficiently define the interval of time which the pitch denotes, whatever musical sound we analyse.

The fact is capable of demonstration so absolute that it does not admit of cavil. Savart's wheel, well known to acousticians, answers the purpose.

Musicians should, therefore, alter their way of thinking, and, if possible, of speaking; should avoid the statement of numbers specifically of vibration, but express pitch by designating the equivalent fractional part of a second. It is always time-distance between any two pulses or vibrations that determines the pitch of a musical note.

Grasp this idea of time-distance, let it be, as it be, as it were graven on the grey tablets of the brain. Try and think of sound in all its phenomena of vibrations and beats as based upon time-distance alone, and of this as governing all the relations of consonances, and dissonances, and harmony.

SECTION VIII.

Tuning Schemes in Practical Work.

Laying the Bearings.—As one octave is the pattern of all octaves upon the keyboard, the gradations to be observed in tuning and tempering the twelve notes of one octave are merely copied in the twelve notes of both higher and lower octaves, and the judgment of the tuner therefore concentrates itself upon the process in or about the central octave, which process is termed "laying the bearings." The great mystery is imagined to be unveiled when the secret of laying the bearings is laid bare, and tuners are commonly highly jealous of admitting amateurs to initiation.

Learning the Methods.—Laying the bearings, or laying the scale, is done upon two distinct methods, the short method constituted of a succession of fourths and fifths only, and a longer method which includes intervening octaves to each, and is surer for beginners. Highly practised tuners prefer the short method, as they can accomplish it in less time. Estimate the fifths first perfect, else you may be deceived by getting the beats the wrong side of the interval, sharp instead of flat.

SCHEME FOR TUNING UPON THE SYSTEM OF EQUAL TEMPERAMENT.

The scheme of fifths, with octaves.
Principal C.

Here only the ♯ sign is used, prefixed to each note singly as it arises; cancelling signs are considered unnecessary, the similarity in the indication is an aid in following the scheme throughout the scale. The sign V means movement downward, and the Λ upward.

As will be seen, every note in the compass from F in the bass to treble C has been included in the tuning, consequently if the adjustment of the fifths and octaves has been accurate, every interval will have been correctly tuned, and when to these all octaves above and below are added, the tuning of the series will be complete. But this consummation devoutly to be wished is too great to be hoped for in such an early stage of a tuning career. Many trials will be necessary, much harking backward and forward, doing and un-

doing, and it will be long before you succeed in giving even yourself satisfaction. Nevertheless, be not discouraged, patience overcometh. Success in the end will depend upon your own skill of hand, your sagacity in discerning proportion, your patience in careful doing. The temper of the sportsman is what is needed; an alertness of mind quick to observe this rising beat and hit the object flying. The organ and the harmonium are to a learner much easier to tune than the pianoforte, for the reason that the notes can be kept permanently sounding until the rate of beating is beyond doubt—the marksman is, as it were, shooting at a fixed mark, and can take time— ;—nevertheless to become a good tuner you have to cultivate an alertness, and a readiness of decision that will enable you to hit your game flying. This promptness it is desirable to rely upon although you may make many mistakes in judgment, for it is the acquiring of the habit that is of the first importance in your training, and after a while it will be as a second nature to you to decide quickly. This is said to encourage you not to give way to overweening confidence. When it comes that you have attained your purpose with satisfaction, you will be well content with the trouble you have taken *to attain*.

Learn to labour and to wait.—Your first attention as a learner should be directed to practising upon a keyboard the *order of this process* of tuning. Take a dozen or two of little squares of gummed paper (strips from postage stamps answer if at hand) and number them, and place them as you go from key to key, and you will soon see how the octave is filled up, and be able in a short time to become quite familiar with the routine to be followed.

Concerning ourselves with the above scheme, which

is the one usually placed before learners—others will be given subsequently—we have to notice that it is formed entirely of one kind of interval: it is a circle of fifths, which, by *octaving*, is confined to the limited range of one octave and a fourth, and is in the middle portion of the instrument, because in the lower range the bass notes are too often mixed with the sympathetic vibrations of other pipes, and with their own upper partials, which sometimes have greater intensity than the notes themselves, and perplex the ear; and then in the higher range the beats become too quick and indistinct, because, as Helmholtz has shown in his great work, "Sensations of Tone," many of the higher harmonics are beyond the range of human hearing.

Some tuners prefer taking their first G downwards, from the C, really a fourth, but the after course comes pretty much the same.

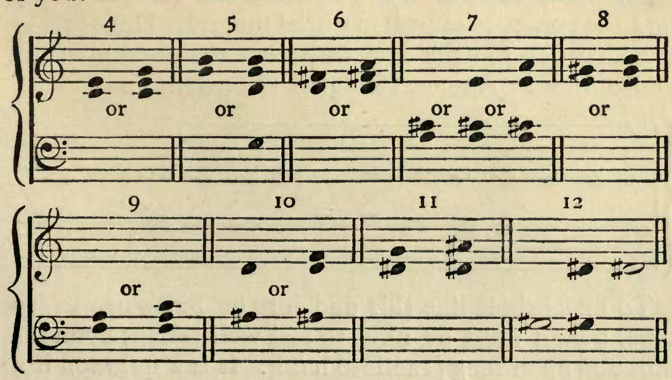
The first C stands as the note of the tuning-pipe (principal C in the treble) and to this the note mid C is tuned perfect. Then follows the G (at first, estimate it perfect), and then make it a flat fifth to C, and then octave to G, and so on. The black note is used to distinguish the note to be tuned, and the white note is the tuned note from whence the next interval is taken.

Upon arriving at the eighth fifth of the series, instead of proceeding onwards in the circle to D♯, it is found more convenient to return to C, and start again, this time taking a fifth down, C down to F; this is called taking a fifth *backward*. In adjusting these latter fifths (nine, ten, eleven) it is better to judge the lower note perfect, and then sharpen it in the same degree as a *forward* taken fifth would be flattened. By this means, as you will readily understand, the interval is still a

diminished or flattened interval, as the lower note is brought nearer to the upper one.

You will probably have to go over the *bearings* several times before it will be safe to assume the correctness of them, and it would be a waste of time to be tuning the remainder of the octaves until this groundwork was satisfactory; for in this one octave is the pattern or model to which all the other octaves are as copies. Indeed, in the course of this routine in laying the bearings it is customary to try by ear the suitableness of the condition of each chord as the notes become available. Thus, the correctness of the note forming the fifth No. 4 is ascertained by associating it with the C below it, and observing whether when struck together these notes produce a major third somewhat sharper than perfect, but still sufficiently near consonance to pass as agreeable.

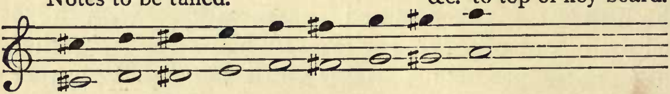
These trials, as they are called, afford at each step a check by which the correctness of the progress may be indicated, or, unfortunately, probably the incorrectness of your first estimates of "how much" and "how little."



The last is the severest test, as the two notes of which this fifth is formed have been *obtained* by different series of fifths, and any imperfection in the gradation of the beatings allotted to the previous fifths will manifest itself here. Hence this fifth, from the frequent harshness and howlings of its beats, has been technically termed the wolf, and strict injunctions are, "Look out for the wolf." Reckon yourself fortunate if no wolf appears.

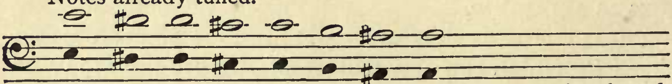
When the bearings are laid with sufficient accuracy, only octaves remain to be tuned, which must be done in the following order :—

Notes to be tuned. &c. to top of key-board.



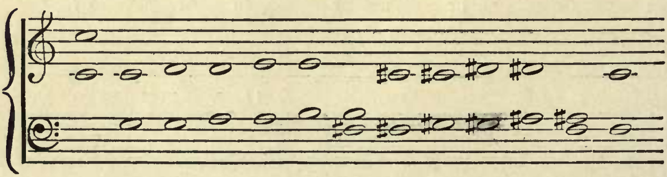
Notes already tuned.

Notes already tuned.



Notes to betuned. &c. to bottom of key-board.

The scheme by Fourths and Fifths only.—This is according to the practice of well matured tuners. This scheme as a chain of fourths and fifths has the great merit of compactness. An octave higher than written.



To make shots like this and hit the bull's-eye every time, a man must be able to feel well reliant upon his skill and upon long practiced habit. It is a question if a

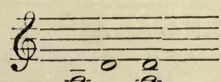
thoroughly seasoned tuner ever stops to think, his brain seems to do it for him; left to itself it may work with an unconscious automatonism surer than calculation.

My New Scheme on the Basis of the Fourth Applicable to all Keyboard Instruments.

The great significance borne by the fourth in the demonstrations in the previous section, will account for the presentation of my new scheme to the attention of every learner, whether amateur or professional. I cannot expect the matured organ tuner to begin again, indeed it might be no gain to him to venture on a new experiment in preference to ways on which he had long by habit trained himself to rely, but I do know that organ builders who have tried my scheme found that they were able to get through the work in half the time, and to do it more accurately.

With confidence I can advise every earnest student of tuning to practice it on a free reed instrument at home, assured that when once mastered the preference for it will continue.

My Scheme for a Learner.—The scheme is based upon the fact that the first fourth, A, D, gives to the learner the standard by which all his after work can be estimated. He possesses a chart of the progressions of the fourths, which is not vague, and does not alter.



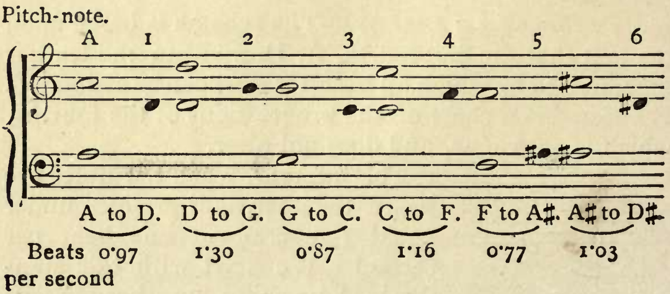
This interval, when the notes are heard together, will produce under equal temperament one beat per second. We start with this standard, advancing up through the

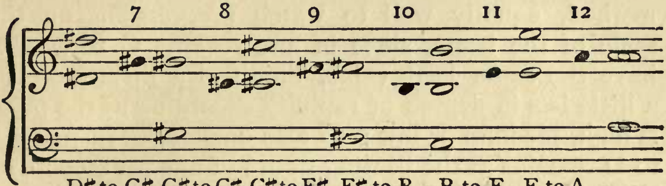
series of the fourths, step by step, the beating distance contracting, until reaching the octave above the fourth started with, when the beats will be found to have gained in rapidity, and to have become two beats per second.

Perhaps, a more influencing reason, is, that starting from A and traversing a chain of fourths, one is more free from the dominating *predisposition* to favour the key of C. Moreover, the learner is able to judge simultaneously of fourths, fifths, and octaves, of the correctness of them in relation to one another *at every step* taken in the progression of the scale.

The method is very simple: to start with the octave, then interpose the fourth, tune and time it, and by it test the truth of the octave; then use that fourth, to start the octave to itself, then interpose the fourth, always the fourth to the lower note of the octave, and so on, and the process brings you back to the note started from.

My Tuning Scheme on A, by Octaves and Fourths.





D♯ to G♯. G♯ to C♯. C♯ to F♯. F♯ to B. B to E. E to A.

1·38 0·92 1·23 0·82 1·09 1·46

The scale of fourths is thus completed in two octaves. There is no lost time, inasmuch as every note is now tuned, and every interval within that compass also properly tuned, *if* the fourths have been, and their octaves. The last or twelfth fourth that is required to E should prove to be exactly the A, the original pitch note started with.

Should it be so, the inference might be that the whole of the compass had been rightly adjusted, and each fourth tempered truly for its position. A little reflection will show you that, though the inference might be justifiable if the result had been arrived at by a practised tuner, it is not to be relied upon by a learner; and therefore the whole work will need to be carefully looked over to see that in the order of the fourths the beats have quickened progressively, and not "by fits and starts."

The A is commonly the pitch standard abroad, and is the tuning pitch note in orchestral use here and everywhere. It is also in use, particularly on the continent, for the tuning of Organs.

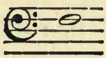
Remember, however, that it is quite easy to start this scheme of the fourths by commencing on C and then proceeding to F for first fourth, and pursuing the

method, equally well to watch progressions on the scale of the beats, since in any scheme C to F will have the same beat value, modified a little more or a little less in degree of rapidity according as the pitch is high, medium or low; so also unchanged in place A to D remains at the beating figure of one per second, or very close upon it.

The beats, for each interval as it arises, having been set out in the scheme, let us now arrange them in a progressive order as a series of fourths through the scale.

This is the order from note to note upwards :—

Bass or Tenor F.

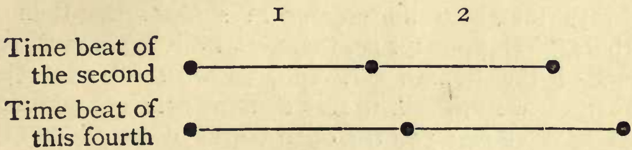


5	F	to A♯	.	·77
10	F♯	„ B	.	·82
3	G	„ C	.	·87
8	G♯	„ C♯	.	·92
1	A	„ D	.	·97
6	A♯	„ D♯	.	1·03
11	B	„ E	.	1·09
4	C	„ F	.	1·16
9	C♯	„ F♯	.	1·23
2	D	„ G	.	1·30
7	D♯	„ G♯	.	1·38
12	E	„ A	.	1·46

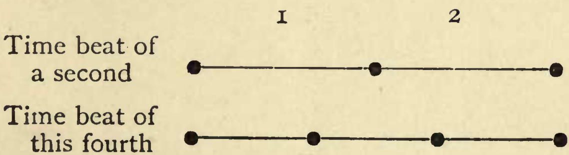
So that when you sound these fourths in this succession, they should perceptibly quicken in their beatings in this proportion, as tabularly set forth. The notes that are above treble A have been tuned as octaves; but if they are correct, they should, in their relations of fourths, carry on the progression from treble F to . . A♯, and in succession, arriving at B . . . E, each one doubling

the rate of beating of those the octave lower, stated in the table above.

The first rate given you will notice is 0·77; this means that the time-distance between each beat is longer than the time of one second by the difference between 77 and 100; that is, it extends beyond the fifth part of another second, represented thus:—



And the time distance of the beat of the fourth E—A, the last of the series, is 1·46. This means that it is less than the time of one second, as at about 3 to 2.



The fourth has always seemed to me the most naturally selected interval for tuning. It prevails in Arabia, in Persia, in China; and was the decisive interval in which Greek music and Greek scales originated. Mr. A. J. Ellis came at last to the same conclusion. He says: "The fact that the Greek scale was derived from the tetrachord, or divisions of the fourth, and *not* the fifth, leads me to suppose that the tuning was founded on the fourth, not the fifth. . . . It is most convenient for modern habits of thought to consider the series as one of fifths; but I wish to draw attention to the fact

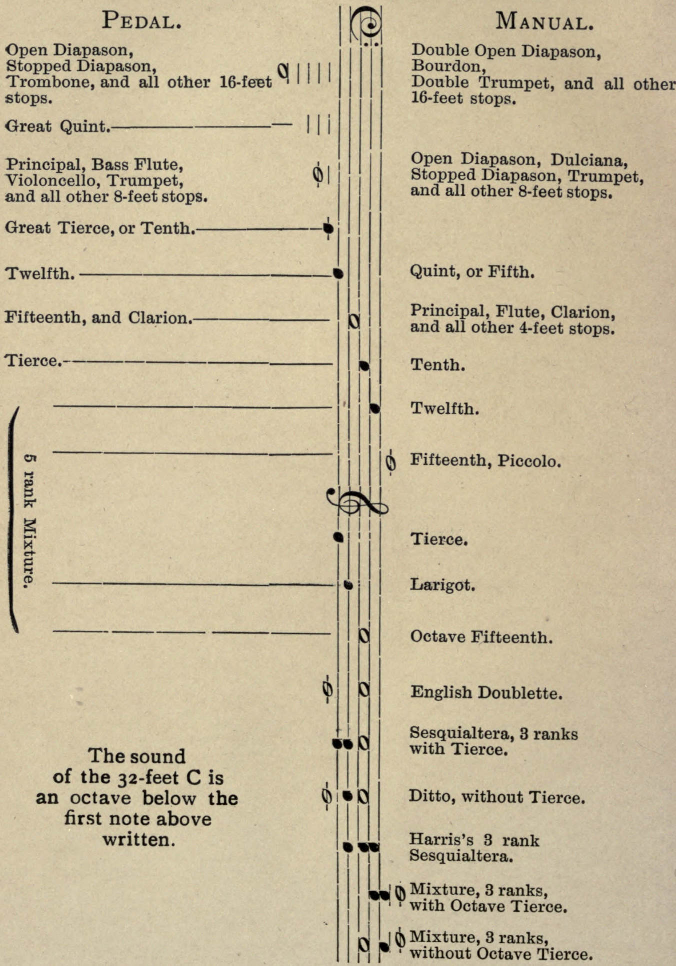
that in all probability it was historically a series of fourths."

That you should obtain the accurate progressions tabulated for your guidance is not to be expected.

Mr. A. J. Hipkins, who speaks from ripe experience, says: "Perfect accuracy is indeed impossible even with the best-trained ears . . . . practically, the error is always found to be greater in some fifths than in others." Happily for us, there is a limit to the sensitiveness of the human ear, and, as with all our other faculties, we are fain to rest content with compromise.

I have shown you the open truths of nature and the high demands of art, and you are none the worse for having before you a counsel of perfection.

Table of the Sounds produced by the several leading Manual and Pedal Stops from the low C key.



Hermann Smith's "Modern Organ Tuning."

SECTION IX.

Reinstatement.

The completion of the task.—Having shown you the How and Why of Organ Tuning, having demonstrated the theory and principles of the System of Equal Temperament, making clear the scientific basis upon which, consciously or unconsciously, methods of Tuning must rest, having provided you with ample tabular calculations and with the most useful schemes for carrying out your work, that are known or are in general practice, I think I may consider that my task is done, for this book makes no pretension to instruct in Organ Builder's work.

There remains little more to add, and that little is of a supplementary nature, as of advice, and comments, afterthoughts and the like, which could not well be introduced in earlier sections.

In the plan of this book I have supposed myself to be addressing, firstly, the young learner of organ tuning who is somewhat experienced in factory proceedings ; secondly, the amateur who has learnt about organ building from one or many books, and perchance has built an instrument for himself or for others ; thirdly, the organist proper who has had an observant knowledge of the construction of organs, seen them in the making, and maybe is so circumstanced that at times it is necessary he should see to matters himself, rectifying and regulating action work, and tuning pipes that have gone astray, and should he be of

what is called a mechanical turn of mind, things may go well.

The learner, the amateur, the organist,—these men willingly accept theory as an aid in the quest of what they are "wanting to know," and will resort to book-learning gladly. The old factory hand, however (and perhaps also the master builder himself), is made of sterner stuff; to talk to him of theory is an imprudence, for like the red shawl in the face of the bull it provokes his ire and contempt; he has got on without theory, "a fig for theory," he says, "give me practice," forgetting that all the routine of his life is based upon theory. Lord Kelvin in one of his latest utterances pleaded for the recognition, by all workers, of the alliance of theory with practice. "Theory" is a conception that we shall find facts in a certain order of relation, and the statement of a theory is in its logical relation to practice an invitation to prove by practice whether it has been stated correctly, or has been imperfectly stated. You will often find persons confirmed in the foolish notion that theory is opposed to practice, and much contention is engendered over a term in order it would seem to boast of the superiority of practice. Young tuners will, I hope, accustom themselves to the more intelligent view, that in industry as well as in science the two are naturally allied, and will perceive that practice is itself but the effect or result of foregone theory.

The Organ Tuner not a free agent.—The tuner who has a proper regard for his work makes a general survey of the present condition of the instrument before proceeding with his task. Sometimes he is not even at liberty to do that, for he is sent merely to do certain

things, instructed to rectify some faults of tuning in a particular stop or stops that are pointed out, to attend to some defects in the action, and then to come away.

The organ tuner in whatever capacity we take him is not a free agent. Even if entrusted to tune the whole organ he is under restraint. In point of fact all that he is called upon to do is to bring the organ as far as possible back to the condition in which it was when first set up and finished. He must not alter the pitch or interfere with the quality, the voicer at the factory has determined these finally. His office extends not beyond simply—reinstatement.

How to proceed by routine.—At periodical tunings regularly arranged for, the presumption is that everything will be attended to, and the organ be left in a well ordered state throughout. In the general survey the first point for attention is the wind supply. The bellows should be visited to see that it works properly, that the weights are evenly distributed to keep a level balance whilst working, for some blowers are very careless about this. The tell-tale should stand at some ascertained best height for steadiness, usually agreed to be that indicating the bellows half full; the tell-tale should also be watched at the keys for indication of wasting when no notes are being held, or for irregularities betraying themselves when certain stops are drawn on. Nothing should be done in tuning without first seeing to the regulating of the level of the keys, for if any are out of level it is a sure sign of something requiring looking to in the action-work between the key and the valve. The pitch of every pipe depends so greatly upon the full opening of its supply valve that attention

to this is of primary importance and much after trouble is saved by care taken at this stage.

The draw-stops should next be proved and the slides also to see that each draws out to its proper distance, since the quality of a whole stop may be deteriorated in neglect of this particular. Then every stop should be run through on the keyboard and note taken of all errors of pitch that are strikingly wrong, and after that a vigilant ear given to detect deviations in the run of the pipes from their special quality as components of the stop under investigation ; these faults may be due to deficient valve opening or to some misplacement of the pipe by accident or from negligent movements in the previous tuning.

Why " The Principal " stop is chosen to rule the tuning. —The Diapason work of the organ receives the first attention, and the Principal is the stop that gives the pitch to the whole. Some prescient musicians express wonder that the 8ft. diapason should not be chosen for the purpose, since to them as players it is the governing power. The tuner, however, knows or should know that one little pipe, nominally a foot long, is the master key, is the real ruler of the pitch, for to it the whole instrument in its making is subordinated. The organ when it is complete is still controlled by this little pipe which stands in the stop Principal 4ft., and it answers to the key, which, as the keyboard represents the 8ft. range to the eye, is there called middle C, and speaks the note that is likewise middle C in music between the treble and the bass staves.

In laying the bearings for tuning it is found that this stop is the most free from liability to be disturbed by the perplexing influence that goes by the name of

"sympathy." One of the greatest of the tuner's troubles is the presence of this sympathy, that is to say, of a pipe being drawn away from its proper pitch by other pipes of larger body setting up an answering vibration to the pipe that is being tuned, thereby impairing its accuracy in tune. The flute stops are particularly prone to the exercise of this troubling influence. When a pipe that is being tuned evidently yields its independence to the malefic interference of an outsider, very probably some pipe close at hand is the culprit because proximity in pitch consorts with proximity in position to this end; when the pipe is found the evil influence is averted almost always by turning the pipe so that the mouth shall face in a slightly different direction. Sometimes it is some larger pipe that interferes by its harmonic tone slightly at variance with the lesser pipe that is being tuned, at other times sympathy in pitch is shown by rattling of a glass pane in the church window that is by chance responsive in vibration. The use of the term sympathy is convenient, and we are accustomed to apply it as opposed to coercion, but strictly viewed, this response named sympathy, results as a mild form of coercion, it is as purely a dynamic effect as the swaying of trees to the wind. In the instance under consideration the lesser pipe, the one being tuned, does by its vibrations awaken the larger pipe, which, in turn vibrating, disturbs the activity of its disturber. Of sympathetic resonance it is equally true that it is coerced resonance, the mildest form of it it is true, yet a question of degree only.

How the Flue Pipes are to be identified.—The organ is usually spoken of as consisting of two classes of pipes, the flue or flute pipes, and the reed pipes. This division

however, is inadequate, and the words conjoined "flue or flute" misleading, since the majority of the pipes are not flutes although they may with truth be said to be whistles. Quality is now the important feature of identification, and the tuner should think of the flue pipes as divided into three main classes :—

The Diapason work, including Principal 4ft. twelfth, fifteenth, and mixtures.
The Flute work, or liquid toned, including Gedacts, and stopped pipes.
The Gambas or string-toned pipes.

The qualities of these as indicated by their names should be in mind in Tuning, even as each quality was in the original voicing. That is the important thing, because each of the stops has its own particular characteristics in "*beating*," with consequently different effects upon the sense of hearing.

Similar chords beat differently in different stops.— A chord of Flute tone must not sound as the same chord would in the Diapason tone or in the Gamba tone, because in the two latter kinds the harmonics that are beating are more in number and in range; and in the Gamba more discording harmonics enter into the combination than in the Diapason, and reach higher in the scale. Scale is here used as musicians use the term to denote a certain succession of notes, whilst the organ builder has a totally distinct meaning to it ; scale to him indicates the width or diameter of pipes, and it is upon the scale or widths of pipes, and the size of the mouths, and the cutting up of the mouths, that the qualities of tone chiefly depend. The Flutes are cut up high in order they may not develop harmonics, for the

true flute tone has but little. For the Diapasons the mouths are not high cut as in the Flutes, else they would not be Diapasons, for the true grandeur of Diapason is in its compound of harmonics growing out of the foundation tone, duly apportioned in power and in brilliance. In the Gambas the mouths are cut the lowest and the pipes are slender, hence the ground tone is lessened in strength, and the full string of harmonics gains prominence in a characteristic manner, bringing out some upper tones that conflict and give the desired pungency in the blend, representing violins and 'cellos.

The tuner who is by nature fit for his vocation should keenly feel the presence of these distinct qualities in the stops, should watch from pipe to pipe for any failures, and equally for any that display themselves too preponderant in their rank. Very necessary it is that emphasis should be made upon this point, for some tuners are heedless and leave the instrument without regard for any matter but the tuning. Pitch alone will not decide the question of good tuning. For instance, it is quite easy to bring a faulty pipe into tune, yet leave the real fault causing the *out-of-tuneness* unremedied. Such a pipe the voicer would know instantly has been thrown off its quality by some interference with its wind supply, an accidental pressure on its lip, or lodgement of obstruction in windway, or other cause, which seen to, the pipe would come back to its original pitch, not needing tuning. The tuner should hold himself bound by the original quality which he must not tamper with, neither heedlessly overlook.

Since the beatings displayed under temperament *are made by the harmonics* existing in the ground tone (a fact easily demonstrated by science), it follows that

flute-pipes being almost barren of harmonics, that can be recognised in strength, are difficult to tune with exactness; stopped pipes also are similarly troublesome, and the tuner is frequently satisfied at the time, when in truth he ought not to be, and finds it out afterwards when the ear is fresh, and some other stop calls out the error for further attention.

I have remarked upon the discording harmonics, and as I find some musicians do not investigate the matter to the point of understanding, a little explanation here may be interesting, or at least useful to those who cannot indulge in the study of acoustics.

The growth of the Harmonic series.—Prefacing this section you find a table of the building up of the mass of sounds of the organ, as the process is looked at by the organ builder and by the organist, for both take the empirical estimate, with a convenient deference to Nature but only so far as she pleases them. Out of the harmonic series which, as they admit, "Nature dictates," they pick and choose, and whilst seeming to defer, have their own way, and rightly so. In fact they set experience above Nature, and follow her dictates instead, as is the human way. The table is taken from the standard work on "The Organ" by the late Dr. E. J. Hopkins, and coming from so accomplished an organist it is authoritative as to established custom in practice and expediency arrived at after many centuries of progress and experiment.

As organs grew apace in bulk and power, it was felt by musicians that the full organ needed brightening, and the known deficiency of the flute tone pipes and stopped pipes in what was recognised as harmonic quality, gradually led to the introduction of harmonic or

corroborating stops, and mixtures or compound stops further carrying out the scheme. It was pure empiricism. What to them sounded well, that determined what the additions should be.

The harmonic series in Nature is a different thing, it knows no breaks, has no repetitions, and it advances in a significant order by steps of ever lessened intervals. Hence it is a real series, and it should be comprehended as such by every tuner.

The term "harmonic" as applied to sounds produced by an instrument of music has two distinct significations, and these in speaking of pipes and strings are often confused. The violinist plays "harmonics" on his violin by a peculiar method of touching or exciting the string, thus isolating the harmonic from the ground tone of the full length of the string; by this method at least twenty distinct harmonic tones may be isolated. Apart from this special origination science has demonstrated that a string vibrating as a whole does produce compound tone, that is to say, that the *one tone* sounded, which tone we specify as the pitch tone, has in it a series of other lesser tones arising in the order called harmonic succession; in this sense we use the term harmonic as indicating compound harmonics, or tones within the tone. These intertones have been variously named, "generated tones," "concomitant tones," "attendant sounds," "overtones," and "clang tint" and "timbre" as accounting for quality in the tone, but custom seems now to have settled down at Helmholtz designation "partial-tones" and "upper-partial tones," this latter separating as a class all those out of or above the ground tone, which henceforth as "prime tone" was reckoned as number one in the series of partial tones.

To musicians who have made themselves acquainted with science the explanation will seem superfluous, but I have good reason to believe that many of my readers will be glad of this simple analysis, comprehensible without resort to studies in acoustics.

The production of harmonics in organ pipes is due to an excess of energy in the exciting agent beyond that necessary to cause a ground tone to exist, one may say, barely to exist. An *overblown* pipe goes off to its octave, suppressing the ground tone. The "*flûte harmonique*" method secures the octave, in consequence of the piercing of a small hole a little below the half length of the pipe, a device which prevents the speaking of the ground tone. This is an instance of isolated harmonic. But a pipe voicer so rules the excess or strength of wind, as to hold it to his will to create harmonic compound tone within the ground or pitch note of the pipe, making a strong, full, mellow, rich, diapason tone. Such a pipe does not overblow; in foothole, windway, lip and languid, and mouth, every part is treated so as to secure the tone the voicer desires.

Orchestral wind instruments isolate harmonics to form the greater part of their scale of notes. In the trumpet as high as the twentieth of the series.

The organ is designed for harmony, yet it presents the apparently anomalous condition, that of its grand array of pipes, one portion is tuned to equal temperament, whilst another large portion is tuned to just intonation. The tuner has to tune the twelfth, the tierce, the sesquialtera, and the mixtures, without the least temperament, in just intonation to the pitch of the pipe sounded by whatever key is pressed down in the course of the scale.

The tuner has to acquire a knowledge of all these pipes, their position and relation, and should make himself familiar with the forms of sesquialtera, shown in Dr. Hopkins' table. Some of the mixtures reach high and not every tuner has a good ear for these extreme sounds. On the other hand there are tuners who are always in doubt of the pitch of very low tones. However hard the task the work has to be got through. The marvel is, as Dr. Hopkins says in reference to the mixtures, "it would seem that no agreeable effect could possibly be obtained from the union of sounds so hostile; but so far from this being the case, not only are most of these sounds capable of the most satisfactory reconciliation, but their presence is positively indispensable to the production of true organ tone."

The law of harmonic progression covers two principles, the first is:—That each harmonic successively elicited has an increase of number of vibrations, exactly that of the number of vibrations of the prime-tone, no more, no less.

the second principle is:—That in the order of ascent from harmonic to harmonic, the intervals between them lessen and lessen, and never repeat.

Thus it follows that whilst within the second octave only one harmonic comes into being, in each succeeding octave the number included increases rapidly until at last in the fifth octave even the semitone interval would be abolished, as we should see if the table was extended, as some scientists carry it even to the forty-eighth in series, when musical chaos comes.

I have given the tempered scale side by side and it is for the tuner to compare these, to see what harmonics are left out in organ schemes, and to note

the degree of discord with the tempered notes, which should be useful in the training of the ear. Mixture stops would not be so much objected to if voicers and tuners exercised a finer care in adjusting their relative strength in the general mass of organ tone, of each organ.

I will set it out in a way that will make the matter clear—read from the bottom upwards.

	Harmonic Series.		Vibrations Harmonic Scale.	Vibration Tempered Scale.
Prime tone vib. 64 times multiplied 16	16	c^5—	1024	1024
384	15*	—	960	966·53
64	14*	b♭—	896	912·28
1024	13*	—	832	812·75
	12	g—	768	767·13
Intervals	11*	—	704	724·08
From 9 to 10, a minor tone	10	e—	640	645·08
From 8 to 9, a major tone	9	d—	576	574·70
From 7 to 8, a (wide tone)	8	c^4—	512	512
From 6 to 7 (harmonic seventh)	7*	b♭—	448	456·14
From 5 to 6, a minor third	6	g—	384	383·57
From 4 to 5, a major third	5	e—	320	322·54
From 3 to 4, a fourth	4	c^3—	256	256
From 2 to 3, a fifth	3	g—	192	191·78
From 1 to 2, the Octave	2	c^2—	128	128
Prime Tone	1	c^1—	64	64

The seventh, eleventh, thirteenth, fourteenth and fifteenth partials are discordant, they will not fit into our scale. It will be seen that in each system only the octaves correspond, all the other intervals will set up beatings with the tempered intervals. So it is evident that in chords there are beatings within beats, in addition to those emphatic beats that decide in our tunings, and quality is affected by their presence. Some persons profess to detect up to the fifth and sixth harmonic in good diapason tone. Diapasons of the ordinary voicing have not "the true diapason ring," and in their compound tone may not include more than the third harmonic partial with definite presence. In gamba tone high harmonics exist and probably to the harmonic seventh a peculiar flavour of that quality is due. The Trumpet in the organ has harmonics which from their clang we may judge to extend beyond the twentieth. Inharmonic partials may also arise through hidden defects in materials and proportions. In pipes that are stopped by wooden plugs or otherwise the octave cannot be produced, but only the uneven numbered partials of the prime.

After the Principal has been tuned throughout, the 8ft. Diapason comes next for attention, and usually the other stops on the Great Manual in the order as arranged in succession for drawing; but there is no fixed rule. Some tuners finish one manual complete before proceeding to the Swell and Choir, but the build of the instrument, the tiring of the ear asking for change, and the heating effect the body standing too long in one place has upon the pipes around, these and other considerations determine the routine to be pursued or how far to be departed from, but in all cases it is generally

agreed that the reed pipes come last of all under treatment; and in the reed department young tuners will do well not to be venturesome.

The Octave does not exist in music.—The term designates the eighth key or thirteenth note of our scale for our convenience, and it is not to be dispensed with; considered, however, in regard to the physical basis of music it has no existence. Every group of seven notes is to be a repetition of the original pitch group; if a repetition in lower range the pitch number is lowered one half, if in higher range it is doubled. Our diatonic scale is a septave, in practice the tuner so regards it, and science so treats it, above or below there are but replicates of seven notes. The fifth is not a fifth of anything, it is not a ratio, it is only a step in the scale by arithmetical succession.

The Unison is the only consonance.—In the analysis of musical vibrations it becomes clear that the consonances and dissonances which we speak of are not of the distinctness of the sheep and the goats. There is but one consonance, the unison: to affirm the octave to be a consonance is to allow ourselves to lose sight of the fact upon which ratio depends, viz., difference. In the vibrations of the octave one half do not coincide with the prime tone vibrations, they come between. In the fifth only one in three coincide, and so on. There can be no dividing line between consonances and dissonances separating the sheep from the goats, the terms only signify degrees of relations departing from unison between pairs or couples of tones sounded together; the whole question is of what is agreeable and what disagreeable *when* the question is referred to human ears, and even that is affected by the mood of the time

being and by associated design in sounds. So the mixtures may add to our zest, they like acids commingling with sweets excite the nerves to just the limit within the boundaries of pain. With the tuner and voicer it rests to present us with mixtures that are abhorrent or that are acceptable.

Here it is that the judgment of the old experienced tuner comes in with telling effect. If he has good musical feeling he can make them beautiful. In the natural series of harmonics the intensities rapidly diminish in the order in which they arise. In the organ mixtures the strength is determined on artificial rules, and the product is that which to the builder seemeth best. Mathematical subtleties are outside the calling, no practical tuner goes about his work to find out "the comma of Pythagoras."

In ultimate analysis sounds are shocks.—The harmonics in a tone consist of a series of shocks within the intervals of slower shocks; they originate all at one source, and are regulated to periodicity and proportional relation by that source. Continuous uninterrupted motion is without shocks; if there were no arrests of motion there would be no shocks. Motion reversed in direction becomes in the phenomena of sound, vibration. Hence it follows,—vibration is an activity tempered by rests.

The tuner is as a hot iron moving about amongst the metal pipes, this he would do well to remember and to take himself away for a time, leaving the pipes to recover the effect of his presence. I have known the heat of the hand at two feet distance disturb the unison of two pipes that had been tuned quite perfect, one of the pipes being beyond the influence of the hand. So it may happen when a tuner leaves his work for an

hour, that he finds upon his return that the metal pipes have not remained to pitch ; discrepancies often being greater than he with former experiences to warn him calculated upon. The tuner's work it would seem is never done, and although he has pride in doing well, yet must he perforce content himself with whatever approach to perfection "the living air" permits him to attain.

I go back 4000 years and read the words of the Old Egyptian, Ptah-hotep, contained in the papyrus that is styled "The Oldest Book in the World":

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